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THE PRESIDENTE PINTO.

THE Chilean cruiser Presidente Pinto, sister ship to the Presidente Errazuriz, was commenced with her sister in the shipyard of the Forges et Chantiers de la Mediterranee at La Seyne in August, 1889. The designs of the hull were prepared by the director of the works, M. Lagane, while the engines were designed and built in the society's engine works in Marseilles.

With a displacement of 2,081 tons, the principal dimensions are as follows:

		ft.	in.
Length		268	4
Beam		35	9
Draught	mean	14	7
	aft	16	5
Depth		23	4

The hull is entirely constructed of steel, the frames and beams being for the most part of the |_____| section. An armored deck of steel, varying at the sides from 1·57 in. to 2·36 in. in thickness, and in the center from 1·18 in. to 1·38 in., is fitted; the highest point of this deck being 31½ in. above the water line.

There is no double bottom, but the hull is divided transversely, below the armored deck, into twelve watertight compartments, while with the exception of the bulkheads of the coal bunkers at the sides of the boilers, it is not divided longitudinally.

The Presidente Errazuriz was launched on June 14, 1890, and the Presidente Pinto two months later. Both vessels are sheathed in teak, Canadian elm, and copper, the sheathing being carried well up above the water line. There are two masts, one forward and one aft of the funnel, each of which carries double military tops, arrangements being made in the interior of the masts for the hoisting of the ammunition to these tops. A conning tower, with a total thickness of 3·15 in., is erected on the fore bridge for the protection of the commanding officer in action. The electric light projectors are two in number, and are situated one at each end of the fore bridge.

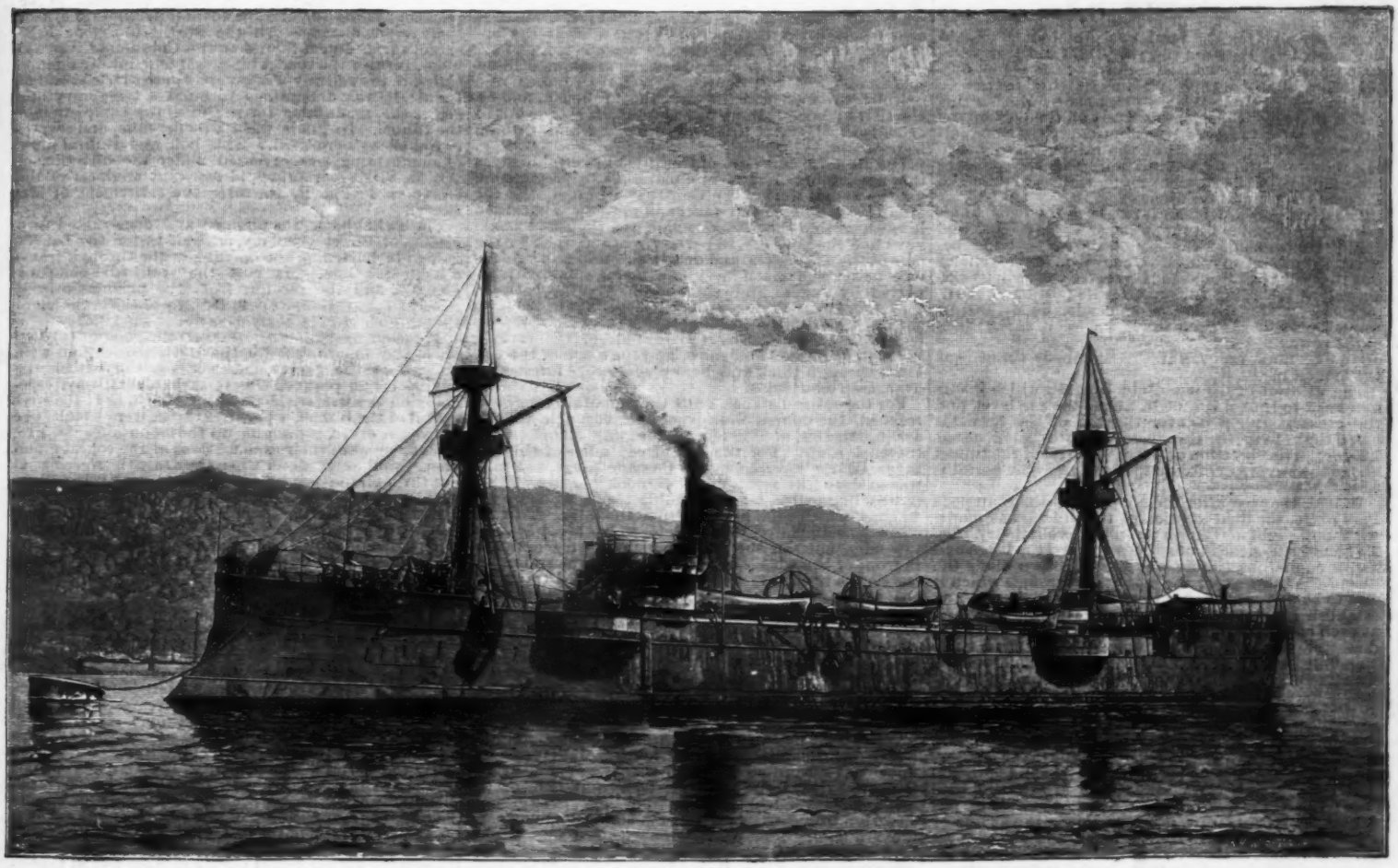
The propelling machinery consists of two triple expansion engines, slightly inclined from the horizontal, placed in separate engine rooms, one forward of the other. On the steam trials the number of revolutions for both ships under natural draught was 140, while under forced draught this was increased to upward of 160 per minute, the speeds obtained being respectively 17 knots and 18⅛ knots per hour, the indicated horse power being 3,560 and 5,500. The air, feed, and circulating pumps are driven in each engine room by a separate engine of the vertical, compound, two-cylinder type.

The normal charge of coal is 170 tons, but provision is made for carrying 230 tons in time of necessity. With the former amount the ship should run 1,446 nautical miles at 15 knots and 2,550 miles at 12 knots; while with the latter and heavier charge the ship should be able to make a voyage of 2,550 nautical miles at 15 knots, or of 4,500 miles at 12 knots.

Four locomotive boilers, each fitted with three Fox's corrugated furnaces, supply the steam for the machinery at a pressure of 160 lb. per square inch.

The sister ship, the Presidente Errazuriz, is armed with four quick-firing Canet guns of 15 centimeters (5·9 in.), placed on sponsons, two on each side; two quick-firing Canet guns of 12 centimeters (4·7 in.), one placed on the forecastle, and one on the poop deck; four quick-firing Hotchkiss guns; four Hotchkiss revolvers of 37 millimeters (1·45 in.); two Gatlings of 11 millimeters (0·43 in.), fitted in the tops; and three torpedo discharging tubes, situated one right forward and one on each broadside.

The Presidente Pinto is designed to be similarly armed.—*Engineering.*



THE CHILEAN CRUISER PRESIDENTE PINTO.

THE STAMPEDE OR CASCADE TUNNEL ON THE NORTHERN PACIFIC R.R.

By CHARLES W. HOBART.

AMONG the greatest feats of engineering skill at the present day is the making of tunnels through mountains of solid rock, under bodies of water, and through the soft earth, for mining and traffic purposes. The ancients caught the idea of tunneling from the works of nature, whose forces accomplished wonderful feats even before man learned to control them for his own convenience.

The deep rocky cañons and caves in this and other countries show the power of running water. In Asia a hill is pierced by a river, forming a natural tunnel through which it flows. There is another natural tunnel of this precise nature in Eastern Tennessee through which a line of railway now runs. The Mammoth Cave of Kentucky, and similar subterranean chambers elsewhere, are instances of nature's tunneling; as also are the caves and tunnels on the seashore, produced by the action of the waves and tides.

By these instances of nature's work in tunneling human effort was inspired many centuries ago. The tombs of kings and other renowned personages of Thebes were tunneled into hillsides for hundreds of feet, and the rock from which the pyramids were constructed was quarried by the Egyptians by driving a long tunnel into the mountain, from which cross and parallel galleries were driven, and large spaces, several hundred feet wide, were cleared, the rock being cut by tube drills, saws, etc. In the days when Babylon was among the greatest cities of the world a tunnel was made under the river Euphrates and arched with masonry. Again, whenever the Roman army, in its peregrinations, required subterranean passages for roads, water supply, drains, etc., tunnels were made. In these early periods the means for tunneling were rude, although the engineering may have been skillful, as was the case in the construction of a tunnel for the drainage of Lake Fucinus, completed A. D. 52. This tunnel was 3½ miles in length, and 23 shafts, some of them 400 ft. in depth, were used, through which the rock and dirt were hoisted in copper buckets by windlasses. We are told that it took 30,000 laborers eleven years to complete this work, which was then the longest tunnel in the world.

Coming down to the present century, the advent of the railway enormously increased the demand for tunnels to open highways through great natural barriers. Within the past 35 years stupendous feats of mountain tunneling for railway uses have been accomplished through the skill of engineers, and the courage and ability of contractors. While full details of nearly all these important works have been given in the columns of *Engineering News*, a brief *resume* of some of them may be of interest.

The Mont Cenis tunnel, 7½ miles long, was commenced in 1857, and was worked by hand drills from both ends, until 1861, when machine drilling was applied. It was completed in 1871, making the total time of construction 14 years. The average progress was 7·71 ft. per day. The average cost was $380 per lineal foot. It is well to note that the cost of labor employed upon this work was only about one shilling, or 24 cents per day, while in the United States similar labor costs from $3.50 to $4 per day.

The St. Gothard tunnel, 9½ miles long, was commenced in 1872 and completed in nine years. Com-

pressed air drills were used throughout, from six to eight Ferroux drills making 180 blows per minute, being attached to a carriage. The average rate of progress was 6·01 lineal yards per day, and the cost was $740 per lineal yard. The system of tunneling adopted was to run upper headings 8 ft. square in advance.

The Arlberg, the third of the Alps tunnels, 6¼ miles long, was began in 1880, and completed in 1883—over three years. The average progress of the work was 9·07 lineal yards per day, and the cost was $540 per lineal yard. This tunnel was worked from both ends, and the system of tunneling differed from the others in that the main heading was excavated from the bottom instead of from the top. Ferroux's percussion drills and Brandt's rotary hydraulic drills were used. Steam dump cars were used instead of mule cars, as in the Mt. Cenis and St. Gothard, which greatly expedited progress. The Hoosac tunnel, which extends through the solid slate rock of Hoosac Mountain a distance of 4¾ miles, was commenced in 1855 and was completed in 1874—over 19 years. It cost the State of Massachusetts about $16,000,000. When the Hoosac tunnel was completed it was the longest tunnel in the world, except the Mt. Cenis. The St. Gothard and the Arlberg, since completed, however, both excel it in length, as above stated. The longest artificial tunnel in the world, however, is the new Croton aqueduct tunnel, extending from the Croton Dam to the Harlem River in New York City, a distance of 33¼ miles. It is 13½ ft. in width and height, and supplies the water for about a million and half of people.

We now come to what was, in some respects, the grandest achievement of them all, when all the difficulties overcome are taken into account, the Stampede or Cascade tunnel.

The Cascade range of mountains extends from British Columbia through Washington, Oregon and California paralleling the coast of the Pacific at a distance of about 75 miles inland for its whole length. Its highest summits rival those of the Rocky Mountain range in altitude.

From the time it was determined to make Puget Sound the western terminus of the Northern Pacific Railroad, the question of a feasible route across the Cascade range for the road was prominently before the company. Between the years 1873 and 1884, several proposed routes were examined by the company's engineers, of which those via the Natches, Stampede and Snoqualmie passes were prominent. During this period there was considerable effort on the part of the city of Seattle to secure the selection of the Snoqualmie route, which would bring the railway to that city as a terminus, and by Yakima and Tacoma to secure the adoption of the Natches route, which would make Tacoma the natural terminus.

The decision was left, however, largely to the judgment of principal assistant engineer V. G. Bogue, who finally recommended the Stampede route, lying between the other two routes. One reason for this choice was that the road would thus traverse the entire Yakima valley, including the most fertile portion of Kittitas county. This route, as recommended by Mr. Bogue, was adopted by the company in the fall of 1884. Each of the routes required a tunnel through the backbone of the Cascade range, but the Stampede tunnel was the longest of the three.

The altitude of the mountain beneath which it was necessary to tunnel is 3,970 ft. above the sea level, and the greatest thickness over the top of the tunnel is more than 1,400 ft., the average depth being about 1,200 ft. The elevation of the east portal of the tunnel above the sea is 2,897 ft. and that of the west portal is 2,800 ft.

In 1885, the year after the adoption of the Stampede Pass route, the final location of the tunnel was made, with but slight deviation from the preliminary line. To secure the greatest possible accuracy, the large and dense coniferous timber was slashed down along the line of the tunnel over the mountain through which it was to be driven, in order to check the alignment and establish bench marks and reference points over and at each end of the tunnel. Tree trunks about 4 ft. in diameter were cut into sections 5 ft. long, and these were piled on top of each other to form signal towers. The line was thus carried over the mountain with the use of long sights and few stations, the latter located as nearly equidistant as possible, thus diminishing the chances of error.

It should be especially noted that only the ordinary instruments were used in making the final location over the mountain, and in carrying the line into and through the tunnel the only extra attachment used was a very sensitive bubble fixed to the axis of the telescope of the transit, at right angles to the line of sight. I am informed by engineers, and through records of tunnel surveys in this and other countries exceeding a mile in length, that special instruments are generally used for such work. As noted further on, the alignment and grade of this tunnel did not vary an inch when the two ends met.

On January 21, 1886, 12 bids were opened at the Northern Pacific offices, in New York City, for boring a tunnel about two miles long through the Cascade Mountain range and completing it in twenty-eight months. Of these bids that of Nelson Bennett was the lowest. The Northern Pacific engineers made a thorough survey of the site of the work and the facilities for reaching it with materials, investigated improvements in rock drilling machinery, and concluded that the work could be done within twenty-eight months. Other bidders of practical experience in such work fixed their figures at double those of Mr. Bennett, because of the limit of time in which the work must be completed under forfeit of $100,000 and 10 per cent. of the entire contract price besides, and because of the great difficulties confronting them in getting their machinery, etc., on the ground.

So short was the time and so grave the difficulties that Mr. Bennett submitted two bids—one for completing the work within the twenty-eight months required under the stated forfeit, and another bid, $100,000 less in amount, conditioned on a release from the time limit and reliance on his agreement to push the work at the highest possible speed. This second bid, however, the company declined to consider; but it accepted the first bid, and a contract was on that day signed by which Mr. Bennett agreed to complete the tunnel within twenty-eight months from January 21, 1886.

Mr. Bennett had been a railroad contractor since 1881, and had constructed over 250 miles of the Northern Pacific through Montana, under the firm name of Washington Dunn & Co., and about 150 miles of the same railway from the Columbia River toward the Cascade range in Washington, on which he was engaged when the tunnel contract was awarded him. One of the controlling reasons why Mr. Bennett bid so much lower than some of his competitors was his confidence in the conclusion of the engineers that the work could be done within the prescribed time. He knew them personally and had done contract work under them, while the other bidders, lacking this knowledge, hesitated to rely on the engineers' close estimates. Another reason was his practical experience of what could be done in hastening work by a judicious selection of men and appliances with which to work.

On the day the tunnel contract was executed Mr. Bennett telegraphed his general manager, Capt. Sidney J. Bennett, at Yakima, to gather a force at once and clear a road to get the machinery on the ground. This Mr. Bennett purchased and shipped while in New York. The equipment consisted of 5 engines, 3 water wheels, 5 air compressors, 8 70 H P. boilers, 4 large exhaust fans, 2 complete electric arc light plants, 2 miles of 6-in. wrought iron pipe, 2 miles of water pipe, 2 fully equipped machine shop outfits, tools, etc., 36 air drilling machines, several tons of steel drills, 2 locomotive engines, 60 dump cars, 2 saw mill outfits, one for each end, telephones for each end of tunnel and each working point therein, and other necessaries of less interest from an engineering standpoint.

All this plant was shipped by rail to Yakima, Wash., then the end of the track of the Northern Pacific transcontinental line. From this point it had to be transported on wagons and sleds a distance of 82 miles to the east end and 87 miles to the west end of the tunnel. The first wagon loads started Feb. 1 and the first compressor boiler Feb. 22, 1886. It took from this time until June 19 to haul the machinery and implements to the east portal and place it in operation, and it was not until July 15 that the machinery reached the west portal—only 7 miles further—and was in place ready for operation. Meantime, however, a force of men reached the east portal Feb. 1, to clear the approach. On Feb. 13 hand drilling was started, and 411 ft. had been driven on June 19, when machine drilling commenced. About March 1, a force of men also reached the west end to clear the approach, and on March 15, hand drilling was started. The work had extended 488½ ft. at this end when machine drilling began, Sept. 1, 1886.

The most difficult part of this great undertaking was this assembling of men and materials in preparation for the actual work. Getting the machinery on the ground was a herculean task; and nothing is hazarded in the assertion that not one man in a thousand would have had the courage to persevere in the work in the face of the difficulties and delays encountered. As before noted, the machinery and material were transported by wagons and sleds 82 and 87 miles between Feb. 1 and July 15, from an altitude of about 500 ft. to that of 4,200 ft. (the machinery for the west end having been hauled across the summit of the divide), through deep mud and snow, and for much of the distance through thick and heavy coniferous forests and over steep mountains.

For the entire distance, until the mountain range was reached, the course was over hills, through valleys, across streams, and much of the way along an untraveled route. For the last fifteen miles of this distance before ascending the Cascade range, the mud was so deep (the result of a "chinook" or thaw) that it was impossible for the double teams to haul the wagons, which sank in the mire to the hubs. To overcome this difficulty, planks had to be brought from saw mills, miles in the rear, and laid down lengthwise in front of the wheels of each wagon of the train. As fast as the train passed over this improvised tramway, the planks were hauled to the front and laid down again. The mode of hauling the wagons over these planks was by block and tackle, with the rope tied to the end of the wagon tongue and a team attached to the other end, while the men guided the wagons on the planks by the tongue. By this means all the heavily loaded wagons of the train were worked along over the 15 miles of miry road at the rate of about one mile a day.

These difficulties passed, the ascent of the mountains began and the obstacles to the journey were increased. Snow was encountered so deep that it was necessary to improvise sleds from small fir trees and transfer the loads of heavy machinery, etc., from the wagons to these sleds for transportation the remaining distance. So difficult and perilous was the new made road, running along gorges 500 to 1,000 ft. deep, and precipitous mountain sides where it was impossible for the teams to haul the loads, that the block and tackle had to be again used for hauling. By its aid the heavy loads were slowly worked along for eight or ten miles until the east end of the tunnel was reached; and part of them had then to go seven miles farther to the west end of the tunnel.

The preparation and organization necessary for this great work were stupendous. Like an army, it required a corps of men to move in advance to cut and prepare the road, build bridges where required and establish camps and way stations. These were located at intervals of about twelve miles along the road from the base of supplies to the tunnel, about the distance a loaded team would make in a day. Canvas tents were pitched and accommodations were provided for lodging the men and teams hauling supplies up to the tunnel. To all these stations supplies were furnished from time to time as required. During the four months in which machinery and implements were being transported from Yakima to the tunnel there were upward of 100 teams on the route and several hundred men. The progress of the heavily loaded teams was so slow—from one to five or six miles a day—that tents and supplies were carried with them and camp was made wherever night overtook them if they failed to reach a station.

Besides the great task of hauling the machinery and supplies to the tunnel, preparations had to be made at the same time for establishing the plant at each end and also pushing the work as far as possible with hand drills. The following extract from the first report of the superintendent of the work to the general office of Mr. Bennett, at Tacoma, will give an idea of the obstacles met in this part of the work:

"FEB. 13, 1886.

"On Feb. 9 I found things at Cascade tunnel thus. Before we could get to the east end of the tunnel we had to shovel a road 100 ft. long through snow 6 to 8 ft. deep. At the face of the tunnel there were 200 miner's in. of water falling from the top of the bluff, 170 ft. above, which had to be turned. We made a cut through snow and ice 20 ft. wide, 8 to 10 ft. deep and 150 ft. long, to get to the portal of the east end. In order to reach the west portal it was necessary to shovel a trail 4 ft. wide and 4 miles long through snow from 4 to 20 ft. deep. The grade of the railroad is 20 ft. below the bed of the creek, and 10,000 yd. of solid rock excavation must be made before it can be reached and also a 1,600 ft. haul for waste dump."

Besides this, houses in which to feed and lodge the men, stables for the horses, saw mills, machine and other shops, stores for supplies, etc., had to be erected at each end of the tunnel. For those at the east end 20 ft. of snow had to be shoveled away to get a ground foundation, and when built the snow was several feet above some of them. At the west end 15 ft. of snow had to be shoveled away for the same number and character of buildings.

The mountain through which the tunnel is pierced is the backbone, so to speak, of the Cascade range at that point. Two of the largest rivers of the State have their source at the foot of this mountain. One, the Yakima, rises a few miles north of the eastern portal of the tunnel and flows eastward to a junction with the Columbia River at Pasco, forming a chain of breaks in the hills and mountains. The other stream, the Green River, rises a few miles south of the tunnel, courses along the western base of the same mountain, and flowing westward from near the west portal of the tunnel, forms a series of passes through the mountains and foot hills to Puget Sound.

The valleys of these two rivers formed a favorable route for the railway line, and enabled it to reach the heart of the Cascade range from either side, where only the main backbone of the range remained to be pierced. Moreover, the broad and fertile valleys of these rivers, along which the Northern Pacific R.R. extends from Puget Sound to the Columbia River, 250 miles, furnish the road with a vast amount of traffic.

Before the railway was completed to the east end of tunnel, it was determined to build a temporary line across the mountains for use until the completion of the tunnel. Its grade was 300 ft. per mile, and several switchbacks were used. This bold and skillful piece of engineering was executed under the direction of Mr. H. S. Huson, principal assistant engineer of the Northern Pacific R. R., after the retirement of Mr. Bogue.

The switchback was planned and constructed as a matter of direct economy, as well as for the benefit gained in hastening the opening of the through transcontinental line. It cost the railroad company $400,000, and the receipts from the business over it from its completion, July 2, 1887, to the completion of the tunnel, May 14, 1888, were about $500,000.

Travelers over the line who had the good fortune to cross the mountains by the switchback line were amazed at the genius and boldness with which the engineer had planned this remarkable railway, especially on the western slope of the range, near the west portal of the tunnel, where five tracks were visible, one above the other, zigzagging up the mountain side. Frequent also were their exclamations at the courage and energy of the contractor when they saw the zigzag road cut through the heavy forest along the steep mountain side up which he had hauled the heavy machinery required for boring the tunnel.

I doubt whether any tunnel was ever undertaken where the difficulties and the cost in reaching the site and preparing for work were so great as at the Cascade tunnel. About six months were occupied in clearing the way and getting the machinery and material to the work, at a cost to the contractor of $125,000, before the tunnel work was commenced. The St. Gothard and Arlberg tunnels in the Alps, and the Hoosac in this country, were attended with no such difficulties, as they were built in old settled countries. Not only were great depths of snow encountered in the Cascade mountains, but the course of two streams of water had to be changed at each end of the tunnel. One of these, at the east end, fell directly over the portal at a distance of 170 ft. from the steep cliff above.

By the terms of the contract, the Cascade tunnel was to be 16½ feet wide in the clear and 22 feet in height, and was to be completed by May 21, 1888, or 28 months from the date of the contract. As we have seen, about six months of this had passed before the machine drills were put in operation, thus leaving but 22 months for the actual boring of 8,950 feet of tunnel, 900 feet having been driven with hand drills during the first six months.

The method of driving the tunnel was as follows: An 8 foot heading was driven along the top of the tunnel, and was kept about 30 feet in advance of the bench, where the tunnel was excavated to its full size. With the exception of about 500 feet inward from each portal, where the rock was firm and stable, the entire tunnel was timbered as fast as the work progressed. The timbers of the heading rested upon the bench, and as that was removed other timbers were put in its place.

The Arlberg tunnel in the Alps was driven by a bottom heading, and at intervals of 100 feet a shaft was driven upward from this heading to the top of the tunnel section and a top heading 6·56 by 8·2 feet was then driven each way from this shaft along the crown of the tunnel. All the work except driving the bottom heading was done with drills. [See *Engineering News*, Jan. 19, 1884.] This made an extremely rapid system of tunneling and a very expensive one as well. As economy of money as well as time was urgent at the Stampede tunnel, the ordinary top heading system was used.

The work on the Stampede tunnel was under the superintendence of Capt. Sidney J. Bennett, a brother of the contractor, and a detailed report was made daily to Mr. Nelson Bennett at his office in Tacoma. From the time the machinery was placed in full operation at the tunnel until its completion, the average number of men employed at the tunnel was 350. They were employed by the day of 10 hours, and were paid from

$2.50 to $5 per day, according to the character of the work and the skill required, wages being paid regularly and promptly at the end of each month. Eating and lodging houses were established by the contractor near the portals of the tunnel, where the men were boarded at 75 cents per day. In addition to the daily wages a bonus was paid to all men working inside the tunnel, as follows: For every foot gained during the month over the necessary average of 13·58 feet per day, each laborer, doing continuous duty through the month, was paid 25 cents extra, and each drill man or expert workman was paid 50 cents extra.

Work was carried on every day and night in the year, requiring two shifts in each end, each composed of about 75 men. Besides these workmen there were the engineers, firemen, carpenters, machinists, etc. The monthly pay roll amounted to about $30,000.

During November the progress was 23½ feet less than the necessary average, and in December the work was delayed by rain, which flooded the east end, and the total progress was 9 feet short. It will be remembered that the drilling machinery did not get into operation at the west end until Sept. 1. Work in the east end with machine drills began about 70 days earlier, making an average of about five months of machine work in the tunnel during 1886. The progress made to the end of the year was 48 feet short of the average required. In January, 1887, there was a gain in the rate of progress over the required average of 24½ feet; but in the seven following months the progress was 360½ feet below that required, so that on Sept. 1 there was 410 feet to be made up. The greatest loss was in May, 1887, when the progress fell 146 feet short of the required amount. This was chiefly due to the flooding of the tunnel, the bad condition of the bottom and the quitting of workmen.

But the difficult task of making up this time was successfully accomplished. In the eight and a half months from Sept. 1, 1887, to the completion of the tunnel, May 14, 1888, there was a total gain of 454½ feet over the regular progress at the rate of 13·58 feet per day. The greatest progress in any one month was made in April, 1888, when the total advance in the two headings was 549 feet, an average of 18 feet per day.

The rapid advance in the rate of progress of the work during the latter part of the time was due partially to the removal of the local engineer under whose immediate direction the work was begun, between whom and the contractor's superintendent there was some friction. A change was demanded of the railroad company by the contractor, in order that the progress of the work might not be jeopardized; and after it was made the advance in the rate of progress noted above made possible the completion of the tunnel in advance of the schedule time.

During the progress of the work there was no little rivalry between the forces working at the two ends to see which would make the greatest daily progress, and also do the largest portion of the whole work. This gave a stimulus that added considerably to the rate of progress.

The length of the tunnel from portal to portal is 9,850 feet—710 feet short of two miles. Of this distance 899½ feet was driven by hand drills, leaving 8,950½ feet to be driven by the machine drills. Averaging the time during which machine drilling was carried on at the east and west ends, we have 21⅝ months as the time spent in driving this distance, making the average rate of progress 413 feet per month.

On May 3, 1888, the drilling forces in the headings met at a point about midway of the tunnel, and the line and levels carried in from each end by the engineers were found to check with a variation of less than an inch. On May 14 the excavation was completed, seven days before the expiration of the contract time.

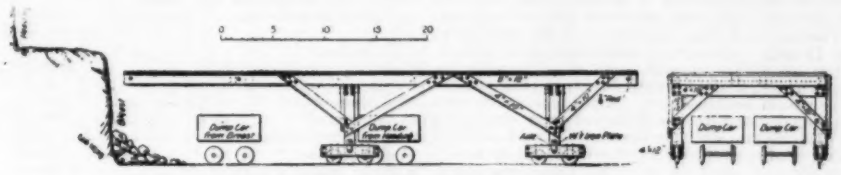
The railroad track was laid through within the next two days; and the tunnel was cleared out and put in shape for use. On May 22 the first regular trains ran through the tunnel.

The total amount of blasting powder used in the tunnel for the entire work was 6,192 boxes of 50 lb. each, making a total of 309,625 lb. This explosive was of several different grades, as shown in the following table:

Kind of explosive.	Nitro-glycerine contained, per cent.	No. of 50 lb. boxes used.
Giant No. 1	60	403¾
Giant No. 2	45	2,123½
Hercules No. 1	60	1,609½
Hercules No. 2	45	1,781¾
Nitro-glycerine No. 2	..	232
Forcite No. 2	..	41½
Total		6,192

The use of powder by months for the first months of 1887 was as follows: January, 439 boxes; February, 368½ boxes; March, 324 boxes; May, 269¼ boxes. The average price paid for all explosives was $10 per box.

Considering the character of the work, the number of men employed, and the fact that it was in progress over two years, accidents were remarkably few. The total number killed during the progress of the work was 13. A hospital was established at the tunnel, where sick and injured workmen were cared for at the nominal rate of $1 per month.



THE "GO-DEVIL."

To Mr. E H. McHenry, now principal assistant engineer of the Cascade or Western division of the Northern Pacific R.R., the writer is indebted for the official maps and the profile of the tunnel and its surroundings published herewith. To Mr. McHenry belongs the credit for the engineering work on the tunnel, as he had entire control of the work during the greater part of the period through which it extended.

Credit should also be awarded to Gen. Adna Anderson, engineer in chief of the Northern Pacific R. R. Co. at that time, for the general supervision of the work. The following data concerning the work were furnished to the writer by Mr. Andrew Gibson, employed as assistant engineer in the construction of the tunnel, and now in charge of the work of lining it with masonry.

The American method or center cut system was adopted, and in blasting from 20 to 23 holes averaging about 12 feet in depth were made in the headings and about 18 holes of the same depth in the benches. Each drill would make, in medium hard rock, 6 or 7 holes in 5 hours. There were times, however, when an exceedingly hard layer of rock would be struck and it would take as much as 15 hours to accomplish the same work. About 400 lb. of powder were generally used at each blast in each of the headings and benches. This would break usually from 8 to 12 lineal feet of tunnel rock. At times, however, in very hard rock, only about 4 lineal feet of heading and about 6 feet of bench would be broken at a blast.

The headings were taken out full size, so that the arch timbering was carried forward on the bench to within about 20 feet of the face of the headings, when the rock was of a character to require this for safety.

The rock through which the tunnel is driven is of a basaltic character, with a dip of the strata toward the west of about 5°. It was necessary to place permanent timbers close to the headings by means of wall plates, the dip of the strata and the general lack of tenacity of the rock rendering it not sufficiently strong to sustain itself in the tunnel. The placing of this permanent timbering required great care, and necessitated compact packing of wood and wedging to secure a continuous bearing upon each segment and make all safe. The timbering necessitated a delay of the drilling and clearing forces or "muckers" of about one-fourth the time, an important matter when time was the vital thing, as in this case.

During the period of hand drilling the number of men employed in each heading averaged about 17 with about 23 muckers, and the daily progress made was about 4 lineal feet of tunnel per 24 hours. During the period of air drilling the number of drills used averaged 5 per day in each end, or 10 in both ends, and the progress made was about 13·8 lineal feet per day of 24 hours, or 6 9 feet per heading.

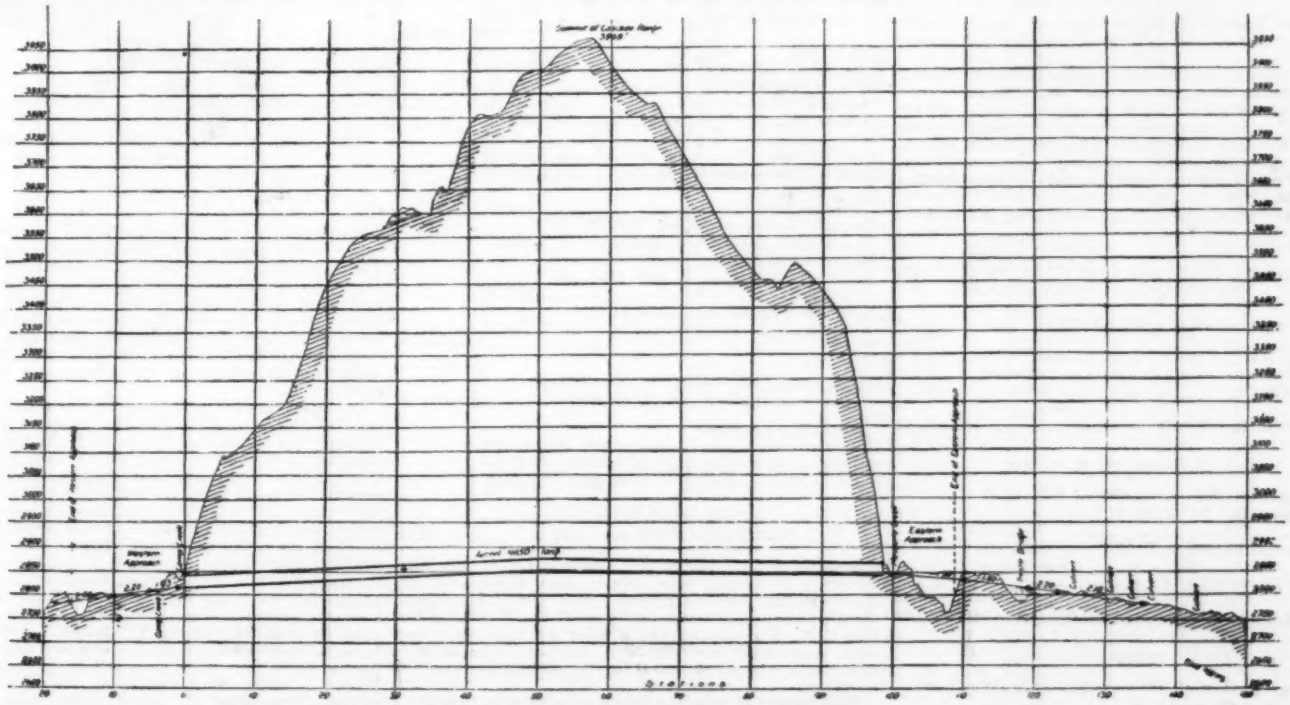
While the contract size of the tunnel was, as elsewhere noted, 16½ feet wide, and 22 feet from subgrade to face of arch, the timbered sections had to be excavated 19½ feet wide and 23 feet 10 inches high, thus requiring 15·70 cubic yards more of rock to the lineal yard to be taken out than in the sections where no timbering was required.

The timbers used for posts, segments and wall plates throughout the tunnel were 12 by 12 inches, and the sills were 8 by 12 inches. Five segments were used in the arch, covered with 4 by 6 inch pieces. The vacant spaces above these to the rock roof were filled with cord wood and other solid packing. The spacing of the bents was according to the character of the rock, but was generally from 2 to 4 feet.

One great obstacle usually found in tunnel work, the presence of underground water, gave little trouble here, except at the portals. In fact, only one spring of any importance was found in the entire length of the tunnel. This was encountered about 2,000 feet from the east portal, and its water was led to the side ditches and got rid of without trouble.

Until the work had extended into both ends of the tunnel about half a mile, mules were used to haul out the dump cars of broken rock. Beyond this point small locomotives were used as the motive power, the grade being so very light that they could haul eight to twelve cars, thus making the cost of hauling out the debris comparatively very light. In mucking out the benches, cars were run up close enough to shovel the rock into them. In taking out rock from the headings, gang planks were used, extending from the top of the benches to a carriage composed of two frame bents, each being upon two wheels, about 18 inches in diameter, resting upon rails 16 feet apart. These bents were connected at the top with 12 by 12 inch caps extending from one to the other, and were strongly braced from caps to bent posts. A platform was built with 4 by 12 inch planks, on the top of which drills, shovels, etc., were placed when not in use. Under this carriage two cars were placed under two openings, through which the rock from the headings was dumped with wheelbarrows. Of this carriage Mr. Bennett says:

"It was used during the construction of the entire tunnel, and we found it of great convenience in expediting the work. The projection leading to the heading was 30 feet in length. The men wheeled the rock from the heading directly on to the platform of the carriage, dumping into a car that stood behind the car used for the bottom or lower work.



THE STAMPEDE OR CASCADE TUNNEL—PROFILE ON LINE OF TUNNEL.

"As seen by the end elevation, this carriage straddled both tracks in the tunnel, and was operated on a separate rail altogether. Before blasting, the men loaded all their tools, etc., upon this carriage, and ran it back from the face for some distance. After a blast they ran it forward again. Thus the men could get to work just as soon as the face had sufficiently cleared of gas and smoke to enable them to find the way. Th upper, or heading, work never interfered with th

lower, while both could be carried on simultaneously. It was a great convenience also in timbering as well as in the manipulation of the electric lights, etc.

"I attribute the rapid work in this tunnel very largely to this device; and while there is no doubt that it can and will be greatly improved, we had no trouble in operating it as shown in the drawing. The men named it 'The Go-Devil.'"

As originally designed this carriage had two endless belt conveyers, one extending out along the front projection, and the other inclined downward to the breast. These were to be driven by a steam engine on the rear of the carriage by chain and sprocket wheel connections, and were intended to automatically convey the rock thrown upon them back to a hopper emptying into the dump car. These conveyers, however, were never used, as with the large number of men employed to push the work it was found they would be too much in the way.

The material pierced by the tunnel consists, to a considerable extent, of shale, which swells upon exposure to the combined action of moisture and air, the result being to exert a great pressure upon the timber lining. The pressure has repeatedly been so great as to reduce 12 inch timbers to a thickness of 4 inches. This action became apparent soon after the completion of the tunnel, and it became evident that permanent lining would be necessary. After careful consideration it was decided that a lining of such character as would exclude the air from the shale would prevent the swelling; consequently that it would not be necessary to provide masonry to resist the forces communicated by the swelling material, and its action upon the timber lining. This having been decided, work was at once commenced, and has been in progress ever since under the immediate direction of the company. The material used in this masonry lining is concrete for the walls and brick for the arch. The concrete is composed of broken stone 5 parts, sand 2 parts, and cement 1 part. The minimum thickness of the side walls is 3 feet. The arch is lined with best brick laid in cement mortar, and at no point is the thickness of the ring less than 2 feet.

The method of constructing this masonry work is briefly as follows: Where the spaces between side timbers or posts are 4 feet, one post is removed, the arch timbers over it being braced and supported by the posts on either side, thus leaving a space of 7 lineal feet to be built up with concrete. Then the posts adjacent to the one removed are left in place, and the posts next beyond them on either side are taken out. This operation is continued until several 7 foot sections of timber are removed, and the concrete built up in their place has become sufficiently hard to support the arch timbers—say in eight or ten days. On these concrete supports the arch timbers are then blocked up; and the remaining posts are taken out and their spaces filled solid with concrete, thus making the wall continuous. Two inch plank, held in place by false posts, are used to hold the concrete in place while it hardens. The mortar for the concrete is prepared outside, and is taken into the tunnel on platform cars having their floor on a level with the top of the walls. On either side of the cars are two spouts, and when the mortar is ready for use, the gates of these spouts are raised and the mortar runs into the space behind the plank with no shoveling. The broken rock is then brought in on flat cars, shoveled into the mortar and mixed with it.

The work is carried on under difficulties, of course, due to the interruption of passing trains. It has been in progress two years and will require several years more to complete.

In laying the brick for the arch the only novelty is in the use of a portable platform on which the masons work, which can be raised or lowered as desired.

The tunnel is lit for its whole length by electric light; the total number of 30 c. p. Edison incandescent lamps used is 296.

The total cost of the Cascade tunnel to the Northern Pacific Railroad Company, under Mr. Bennett's contract, was $1,160,000, or $118 per lineal foot. By its completion the company secured a permanent route across the Cascade Mountains with maximum grades of 116 feet per mile. The accompanying tables taken from the original records show the detailed cost to the contractor and to the railroad company of the work done on the tunnel during the month of November, 1887.

COST OF WORK DONE ON THE CASCADE TUNNEL DURING THE MONTH OF NOVEMBER, 1887.

COST OF WORK TO CONTRACTOR.

Labor	$22,897.75
Material	7,948.72
Miscellaneous	6,581.05
Cost per lin. foot $74.26, or total	$37,427.52

COST OF WORK TO N. P. R.R.

Standard section, 504 lin. ft. @ $78.	$39,312.00
Extra excavation, 1,683 cu. yds. @ $4.50	7,573.50
Timber lining, 160,000 ft. @ $35	5,600.00
Cost per lin. ft. $104.14, or total	$52,485.50
Contractor's profit $29.87 per lin. ft. or total,	$15,057.98

NOTES.

Progress.—East end, 246 ft.; west end, 258 ft.; total, 504 ft.; daily average, 16·8 ft.

Timber.—Lining was required for the entire length excavated in November.

Rock.—Was of same general nature as portion of tunnel already excavated, a soft basaltic, which drills well, but disintegrates rapidly on exposure.

General.—There are no doubt discrepancies in this statement, but the totals are believed to be substantially correct. The month of November was favorable in every respect for the contractor, excellent progress was made (the best since work was begun) and there were no accidents or other interruptions to the work.

EAST END.

Labor.		
Superintendent, ½ mo. @ $500	$250.00	
" 1 " @ $175	175.00	
Master mechanic, ½ " @ $150	75.00	
Engineers, 4×30=120 days @ $4	480.00	
Mach'e repairers, 3×30=90 d's @ $3.50	315.00	
Firemen 2×30=60 " @ $2.50	150.00	
Blacksmiths 3×30=90 " @ $4	360.00	
" helpers, 3×30=90 " @ $2.50	225.00	
Carpenters, 354 days @ $3	1,062.00	
Foremen, 160 " @ $4.50 (average)	720.00	
Drillmen, 293 " @ $3.50	1,025.50	
Chuckmen, 286 " @ $3.00	858.00	
Muckers 1,097 " @ $3.75	3 016.75	
Nippers, 60 " @ $2.50	150.00	
Dumpmen 60 " @ $2.50	150.00	
Car drivers, 60 " @ $2.50	150.00	
Timekeeper, 30 " @ $2.50	75.00	
Lampmen, 60 " @ $2.50	150.00	
Laborers, 550 " @ $2.50	1,375.00	
Bonus to employes for daily progress over 6 feet	300.00	
		$11,062.25
Material.		
82,000 feet timber @ $10	$820.00	
762 lb. wrought iron @ .06	45.72	
62½ cords wood @ $3	187.50	
240 tons coal @ $4	960.00	
900 caps (estimated) @ .01	9.00	
14,400 ft. fuse " @ .01	144.00	
9,000 lb. giant powder @ .16	1,440.00	
		$3,606.22
Miscellaneous.		
Assumed value of plant $50,000, 6 per cent. interest on same	$250.00	
Depreciation of plant 75 per cent. on whole job, 1/18 of 75 per cent. of $50,000	1,339.28	
10 per cent. on all the above to cover all possible omissions	1,625.77	
		$3,215.05
246 feet tunnel all timbered, therefore cost the contractor $72.70 per ft., or total		$17,883.52
November estimate.		
246 ft. tunnel, standard sec. @ $78.	$19,188.00	
821 cu. yds. extra excavati'n @ $4.50	3,694.50	
82,000 ft. timber lining @ $35.	2,870.00	
246 ft. tunnel all timbered, therefore cost N. P. R.R. $104.68 per ft., or total		$25,752.50

WEST END.

Labor.		
Superintendent, ½ mo., @ $500	$250.00	
" 1 " @ $250	250.00	
Master mechanic ½ " @ $150	75.00	
Engineers, 4×30=120 days @ $4	480.00	
Mach. repairers, 3×30=90 dys @ $3.50	315.00	
Firemen, 4×30=120 " @ $2.50	300.00	
Blacksmiths, 2×30=60 " @ $4	240.00	
" helpers, 2×30=60 " @ $2.50	150.00	
Carpenters, 396 days @ $3	1,188.00	
Foremen, 160 " @ $4.50 (ave.)	720.00	
Drillmen, 294 " @ $3.50	1,029.00	
Chuckmen, 293 " @ $3.00	879.00	
Muckers, 1,138 " @ $2.75	3,129.50	
Nippers, 60 " @ $2.50	150.00	
Dumpmen, 60 " @ $2.50	150.00	
Car drivers, 60 " @ $2.50	150.00	
Timekeeper, 30 " @ $2.50	75.00	
Lampmen, 60 " @ $2.50	150.00	
Laborers, 662 " @ $2.50	1,655.00	
Bonus to employes for daily progress over 6 feet	500.00	
		$11,835.50
Material.		
78,000 B. M. timber @ $10	780.00	
800 lb. wrought iron @ .06	48.00	
64½ cords of wood @ $3	193.50	
240 tons coal @ $4	960.00	
900 caps (estimated) @ .01	9.00	
14,400 ft. fuse " @ .01	144.00	
13,800 lb. giant powder, @ .16	2,208 00	
		$4,342.50
Miscellaneous.		
Assumed value of plant $50,000, 6 per cent. interest on same	$250.00	
Depreciation of plant 75 per cent. on whole job, 1/18 of 75 per cent. of $50,000	1,339.28	
10 per cent. on all the above to cover all possible omissions	1,776.72	
		$3,366.00
258 ft. tunnel all timbered, therefore cost contractor $75.75 per ft. or total		$19,544.00
November estimate.		
258 ft. tunnel, standard sec., @ $78.	$20,124 00	
862 cu. yds. extra excavati'n, @ 4.50.	3,879.00	
78,000 ft. timber lining @ $35.	2,730.00	
258 ft. tunnel all timbered, therefore cost N. P. R.R. $103.62 per ft., or total		$26,733.00

Stampede pass across the Cascade range, beneath which this tunnel was driven, was discovered on March 19, 1881, by a party sent out by Mr. V. G. Bogue, then principal assistant engineer of the Northern Pacific R.R. The existence of a pass at this point had been suspected, but was not known prior to this date; and the party was sent out to find the pass, if it existed.

The height of the mountain above the tunnel is 1,135 ft., instead of the figure formerly given.

The switchback over the mountain, over which trains were run during the construction of the tunnel, was executed by Messrs. W. H. Kennedy and J. Q. Barlow, under the direction of Mr. H. S. Huson, as before stated.

In timbering the tunnel, the work was usually done on wall plates. These, with their load of segments, lagging and packing, spanned the space between the last set of posts and the rock of the bench. Additional sets of posts were placed as the excavation progressed.

The breaking shot which established an opening between the east and west headings was fired in the latter on May 3, 1888, as stated. The excavation was completed May 10, and the first regular train ran through the tunnel on May 27.

The line and levels of the engineers working from each end checked as follows: Alignment, 0·046 foot; grade, 0·06; distance, 0·60 foot.

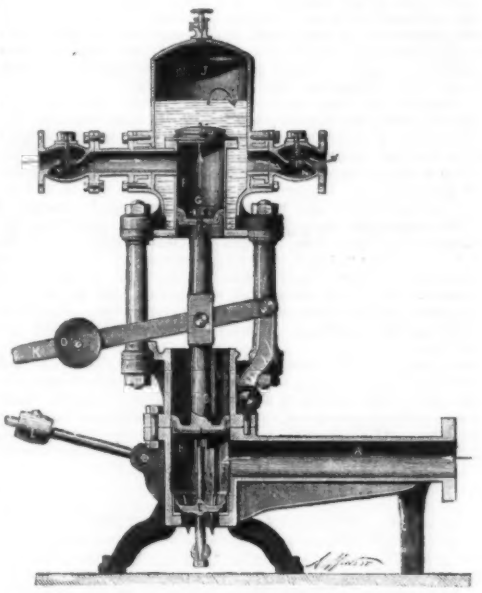
During the month of June, 1888, the Commissioners appointed by the United States government to inspect and accept the successive sections of the main line of the Northern Pacific road were taken through the tunnel by Mr. J. W. Kendrick, chief engineer of the road, thus completing the acceptance of the entire line, by the acceptance of this last part, the most costly work yet done in the West.

The amount of excavation for the tunnel section was 12·36 cubic yards per lineal foot for rock sections and 15·70 cubic yards for the sections where timbering was required instead of the figures formerly given.

In the work of lining the tunnel with a concrete arch now in progress, it may be of interest to note that the sand and cement are mixed dry by a worm mixer at the place where they are to be used. The power for the mixer is furnished by an Edison 6 kilo-watt, 1,000 volt motor, supplied with a current from the lighting dynamo at the east portal of the tunnel.—*Engineering News.*

UNIVERSAL SUCTION RAM.

MR. DUROZOI has recently devised an apparatus of the ram kind, which is still simpler than preceding ones, and the principles of which are worthy of being made known. This apparatus, in fact, utilizes a minimum head of water and is capable of forcing the liquid in a single jet to great heights without the aid of a superposition of hydraulic rams. The result is that the expense is less and that the rendering is increased in large proportions. This new ram is capable of taking up water by suction, even from wells or cisterns situated at a level lower than that of the motive power. Moreover, the difference of the motive pistons and elevators permits of attaining great pressures as to forcing, and, inversely, of using strong heads of water to lift large volumes of another liquid to a less height. The effect of the ram stroke in this apparatus



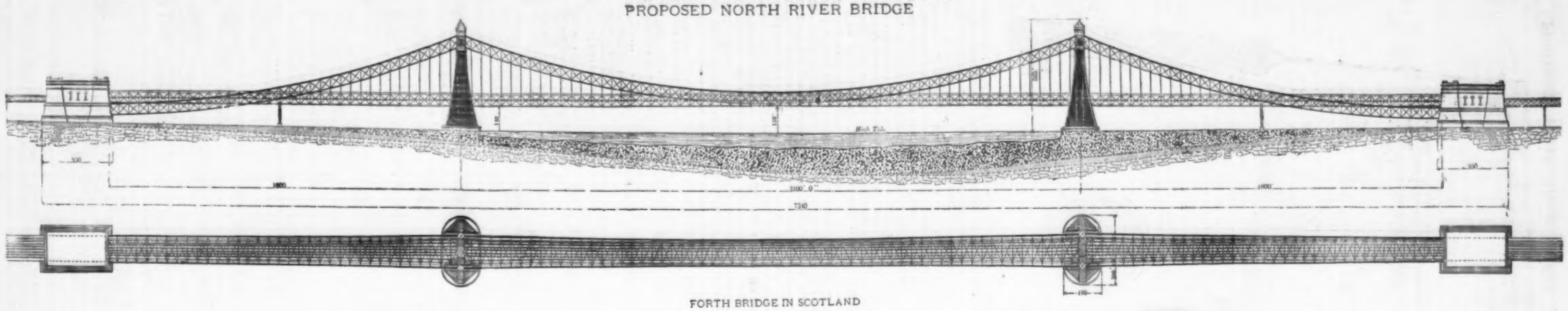
SECTION OF THE UNIVERSAL SUCTION RAM.

is produced normally and directly under the force valve or the piston, and this increases the rendering. There is obtained, moreover, a regulation of the pressures and of the consumption of motive water by the system of equilibrium of the motive valve, and the supply of air is secured at a pressure that balances the force column of the apparatus, and this preserves it from the shocks that occur in ordinary machines, and permits of using it as an air compressor or a suction ram.

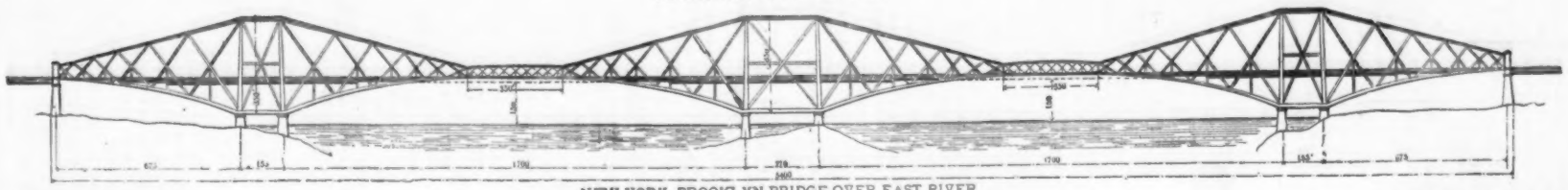
Its operation is as follows: The water, led from the fall by the pipe A, enters the cylinder B, in flowing through the passages of the valve E, which is open. As soon as the normal velocity of the water is reached, the valve E, balanced according to requirements by the counterpoise L, is carried along by the velocity of the water, and is made to rest upon its seat, thus absolutely barring the passage of the liquid, which has reached its initial velocity. The water immediately tends to flow back, through this sudden stoppage, to its upper level. But, as the length of the battery is calculated to resist this recoil, and as it requires a stronger pressure to react against its force of inertia than to raise the piston D, the latter therefore follows the motion of reaction of the water and rises under its impulsion, since it receives the shock directly. Then the piston of the pump G acts as in an ordinary pump. The different liquid that has been sucked up, and has entered the cylinder F through the valve M, is forced through the upper valve H into the air receiver J, and is afterward expelled through the force valve N. The supply of the air reservoir is obtained through a blow valve placed upon the suction pipe.

After these results have been obtained, the valve E, actuated by the counterpoise L, gives passage again to the motive water. At the same time, the piston D, actuated by the lever K and the counterpoise O, redescends and sucks up a new quantity of water, which fills the interior of the cylinder F, and so on.—*Le Genie Civil.*

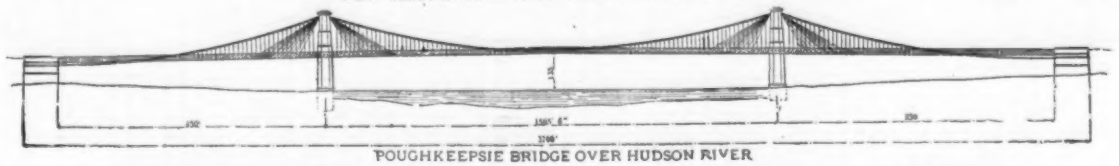
PROPOSED NORTH RIVER BRIDGE



FORTH BRIDGE IN SCOTLAND

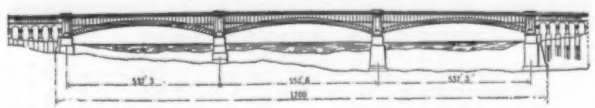


NEW YORK BROOKLYN BRIDGE OVER EAST RIVER



POUGHKEEPSIE BRIDGE OVER HUDSON RIVER

ST LOUIS BRIDGE OVER MISSISSIPPI RIVER



THE PROPOSED NORTH RIVER BRIDGE AT NEW YORK CITY.

THE bridging of the Hudson or North River at New York City has, during the past forty years, been repeatedly planned for the purpose of carrying the tracks of the ten or more railroads terminating in Jersey City across the river directly into the metropolis. But the obstacles to the building of any bridge were considered too formidable to be easily overcome. Naturally a bridge having piers in the river was the only one thought of as feasible. The navigation interests, however, protested so loudly and effectively against the obstruction of the river with piers that nothing ever came of any such bridge projects. Submarine railroad tunnels seemed to be the only alternative, and fifteen years ago the construction of such for two tracks was actually commenced. From one cause and another, but mostly for want of funds, the work has progressed but slowly, and several times was stopped altogether. The prospects for an early completion do not yet appear very promising; but should the tunnel be completed, it would not afford much relief to the railroad traffic across the North river, and which has in the meantime grown to enormous proportions.

The first step toward the solution of the problem by means of a suitable bridge was made five years ago in a proposition of Gustav Lindenthal, the Pittsburg bridge engineer, to bridge the North river at New York with one single span of nearly 3,000 feet, high enough to let tall-masted vessels pass underneath, and strong enough to carry six railroad tracks. Mr. Lindenthal was the first one to make such a bold proposition, which was at first received with much doubt as to its practicability. He published his plans and discussed their practical features of construction, showing that they were not only perfectly feasible, but indeed presented the best solution of the North river crossing yet brought forward. A company was formed, which obtained from Congress the necessary legislation for carrying out this great work. This is "The North River Bridge Company," incorporated by Congress on the 11th of July, 1890, giving them great powers and privileges. (The company's offices are in New York City, at 45 Cedar street, and Mr. Jordan L. Mott, the well known iron manufacturer of New York, is the president of the company.) Since then steady progress has been quietly made in the preparations for the stupendous undertaking. The plans have been modified for a larger bridge than at first contemplated. The finished structure, as now designed, and the plans for which have been filed with the War Department at Washington, provides for 14 railroad tracks and a promenade, arranged in three decks, as shown on the accompanying sectional plan of the bridge. This of itself is such a startling and bold innovation in a bridge design that, coupled with the unprecedented large span of 3,000 feet, it will cause this structure to be looked upon as the *chef d'œuvre* of bridge engineering. Probably in no other place of the world is there such an immense railroad traffic, requiring such a colossal structure to carry it.

The bridge itself having often before been described as to its unique features of construction, we give below an extract from a report of the chief engineer, Gustav Lindenthal, to the board of directors of the North River Bridge Company on the most interesting question of the comparative economy of the North river bridge as compared with other large bridges of the world.

The report discusses the probable volume of traffic to be provided for over the bridge and based on carefully collected statistics of the traffic across the North river, and then discusses the question of location with reference to economy of construction, directness of route, influence of grade and with reference to largest revenue to be obtained from such location, and then contains the following comparison of the economy of its design as compared with other great bridges:

The impression seems to be harbored among those who have given no study to the subject that the cost of the North river bridge will be excessive, because of the long single span of 3,000 feet required over the Hudson river. I hereby submit for your inspection the following comparison with four of the greatest railroad bridges in the world, to make it clear that this impression is erroneous.

The accompanying plan shows on the same scale the North river bridge, the Brooklyn bridge over the East river, the Forth bridge in Scotland, the Poughkeepsie bridge over the Mississippi. Other large bridges might have been added, but the above were selected because each had difficult and costly foundations, resembling somewhat the character of foundation for the North river bridge, except that the latter will exceed in size any of the other foundations, just as the superstructure will also exceed that of the others. The four bridges present different types of construction, and they are the largest examples in existence of each type. The design of the North river bridge is the result of careful study, and was selected from several designs for different types with and without a pier in the river as the most economical and the most suitable for the local conditions. It is confidently believed that no other design can equal or excel in economy and suitability the one adopted for the North river bridge.

The cost of constructing a bridge or tunnel, or any other railroad structure, is usually measured by the cost per lineal foot of track. Taking this criterion, the table shows that the North river bridge will be the cheapest in that respect of all the above great bridges. The total cost of the North river bridge is divided, as is fair and proper, among the ultimate 14 tracks, of which ten tracks are intended for 100 ton locomotives, for the heaviest trains, and four tracks for 50 ton locomotives, for suburban trains only. It is true that only eight tracks are intended to be used at first, and it may be objected that on this account the total cost should be divided among eight tracks. On this basis the result will be $485 per lineal foot of track on the final cost of the bridge. This would still be less than any of the other bridges, except the Poughkeepsie bridge with its short spans. The six additional tracks needed in the more or less near future would then cost nothing more. Per lineal foot of track the North river bridge will therefore cost only about ¼ of the equivalent of the Brooklyn bridge, less than ¼ of that of the Forth bridge, only ⅖ that of the Poughkeepsie bridge, and less than 1 5 of the equivalent in the St. Louis bridge.

Item 9 of the table also shows that the amount of steel and iron per lineal foot of track will be less than in any of the other four bridges with spans so much smaller, when just the contrary result might have been expected.

It can also be shown that the design of the North River bridge with a single span over the entire river is more economical in all other respects than any other design with a pier in the middle of the river. This was the primary reason for proposing it. The other reason was that the national government, in the inter-

COMPARISON OF NORTH RIVER BRIDGE WITH FOUR OTHER BRIDGES.

See plan of bridges.	North River.	Brooklyn.	Forth.	Poughkeepsie.	St. Louis.
1. Type of construction.	Rigid suspended wire cable arches.	Partially stiffened suspension wire cables.	Steel cantilevers.	Alternate cantilever and trusses of steel.	Steel arches.
2. Length of bridge in each case without the approaches, but including the anchorage or abutment	7,340 ft.	3,700 ft.	5,400 ft.	3,100 ft.	1,700 ft.
3. Longest span of each bridge, center to center of bearing	3,100 ft.	1,595 ft.	1,710 ft.	500 ft.	520 ft.
4. Number of railroad tracks that can be used for trains	14	2	2	2	2
5. CAPACITY. Expressed in number of freight trains each 500 feet long, and weighing 800 tons, which each longest span may carry with the same coefficient of safety	20	1½	4¼	2	2
6. CAPACITY. Expressed in number of passenger trains each 500 feet long, weighing 550 tons fully loaded, which each longest span may carry in ordinary operation	30	2	6	2	2
7. Average weight of superstructure per lineal foot of span	lb. 45,000	lb. 7,400	lb. 19,200	lb. 8,300	lb. 8,600
8. Average weight of steel and iron of superstructure per lineal foot of span, without rails, railings and floorings	lb. 42,000	lb. 6,200	lb. 18,400	lb. 7,300	lb. 7,000
9. Average weight of steel and iron of superstructure per lineal foot of track without rails, railings, and floorings	lb. 3,070	lb. 3,100	lb. 9,200	lb. 3,650	lb. 3,500
10. Total cost of construction without approaches, without right of way, and without interest account	$28·5 M	$5·6 M	$13 M	$2·6 M	$5·3 M
11. Cost per lineal foot of bridge	$3,880	$1,510	$2,407	$840	$3,150
12. Cost per lineal foot of track	$278	$265	$1,203	$420	$1,575

est of navigation, rather than permit the obstruction with a bridge pier, recommended through its board of engineers sub-marine tunnels for crossing the river.

The explanation for the remarkable economy of the North River bridge is found in the peculiar conditions available for a very long span bridge for multiple tracks, and not available for successive shorter spans, or for long spans with only two tracks. For instance, the wind bracing must be made enormously strong for such a long span, but it is little more expensive for 14 tracks than for 2 tracks.

The principal bridge members, namely, the four cables, will be made of steel wire having a strength of 175,000 pounds per square inch, and will weigh only one-third as much as if made of steel bars of large section, having ordinarily a strength of about 62,000 pounds per square inch. The North River bridge requires only two deep submarine foundations for the towers. A pier in the middle of the river (200 feet down to rock) would be very expensive, and its omission affords another great saving in this case.

The maximum train loads on the 14 tracks, as designed for this long span, will not likely occur once in 20 years, against those on a double track bridge several times a day; or as compared with the coupled single track arches of the St. Louis bridge, which are strained to the maximum several hundred times a day, that is, from each train passing over the respective tracks. It does not imply that the strength of the North River bridge may therefore be less than for shorter spans, or for less tracks, but, on the contrary, it means that the longer span is so much the safer one, and will, in fact, be the safest ever built.

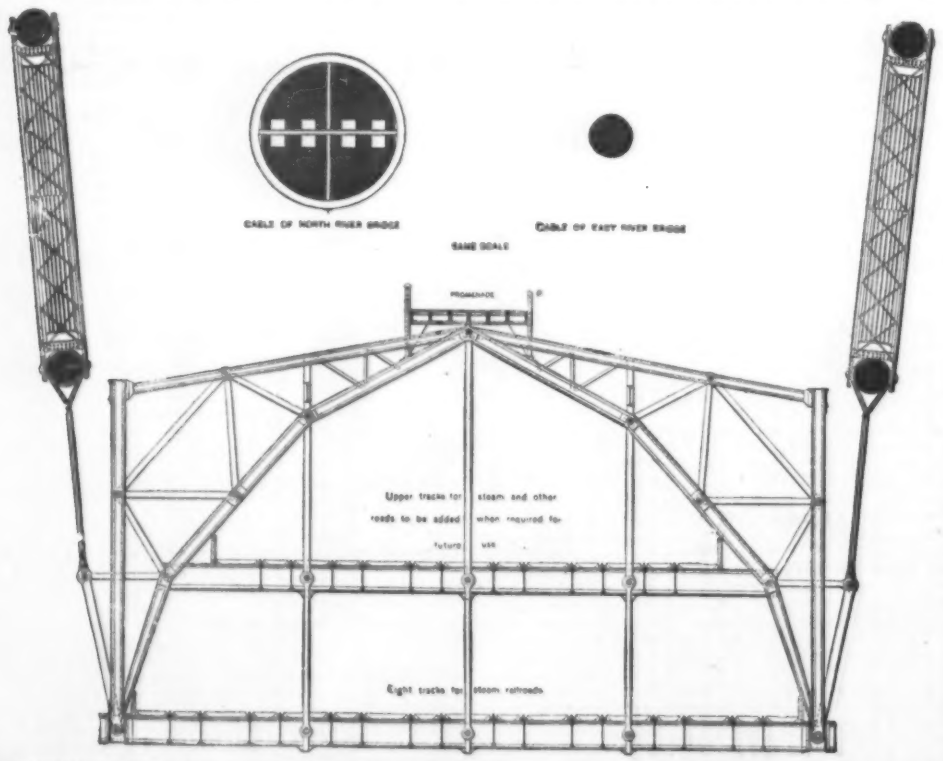
The North River bridge would be absolutely safe if it were loaded on all 14 tracks with locomotives from anchorage to anchorage. It would take 1,800 locomotives to do this. It is an inconceivable event, and the test could not be made, since, for instance, such a great railroad as the Pennsylvania has an equipment only of about 1,500 locomotives. In ordinary operation the trains meeting on the bridge will hardly be 5 to 8 per cent. of the load from the above named 1,800 locomotives.

In point of rigidity, it is sufficient for comparison to call attention to the great rigidity of the Brooklyn suspension bridge, and to note that the latter is only partially stiffened at that. The heavy traction trains sometimes drawn by locomotives, when the cable is out of order, with the dense stream of trucks and wagons on the two roadways, not to mention the load of pedestrians, do not produce excessive vibration. In the North River bridge with rigidly braced cables, and with heavy stiffening trusses, specially designed for the heaviest concentrated loads, and with a dead weight six times greater than that of the Brooklyn bridge, the rigidity will be comparable only to that of solid ground. The only deflections of any moment will be from temperature changes, and those will be so gradual from one season to another as to be imperceptible.

The great economy of the North River bridge design becomes still more apparent in comparison with submarine tunnels, assuming that such tunnels would be as good for railroad purposes as the bridge, which cannot be the case. It is well settled that the cheapest construction of such tunnels through the existing formation is on the principle of one tunnel for each track, and that double track tunnels are proportionately more costly. The length of the tunnels would not be less than that of the bridge, but the cost per lineal foot of track in the tunnel greatly exceeds that on the bridge. The cost per single tunnel, without the approaches, has been estimated by different engineers at about $3,500,000, but it may be greater. In any event, after liberally allowing for economies that might result from experience and repetition of such work, the cost of 14 tunnels, without the approaches, would not be less than $40,000,000, or at least 40 per cent. more than for the bridge. The expense for approaches and for a station in New York City would be greater in the case of tunnels, since the streets must be crossed under grade, below the water line, and the station would be partially under ground. The cost of right of way would also be greater, because of the greater width required for the tunnels side by side, as compared with the tracks from the bridge in two decks one above the other. A speed of 30 or more miles per hour through these tunnels with heavy locomotives would be out of the question, but will be the rule on the bridge. The smaller transportation capacity of such tunnels is as obvious as is the difference in the discharge volume through the same section between a fast and a slow running stream.

It may be remarked that the approaches to the North River bridge will be free from grade crossing with the streets. The tracks in New York and Hoboken are above the streets, and in Jersey City Heights the tracks will run through an open cut with all the street crossings overhead.

The principal expense for an entrance into New York City will always be for the costly right of way which must be acquired; but in New York City, it may be remarked, this cost is not likely to be so great at present as it was and is, for similar improvements, in cities like London, Paris, and Berlin. The expense for right of way and for a passenger station in New York City is not materially affected by the number of tracks on the bridge arranged on two platforms, one above the other, limiting the width of right of way to be acquired to the smallest practical dimensions. Such a saving, as already mentioned, cannot be obtained from submarine tunnels, nor indeed from any other arrangement yet proposed.—*Railway Review.*


CABLE OF NORTH RIVER BRIDGE
CABLE OF EAST RIVER BRIDGE
SAME SCALE
PROMENADE
Upper tracks for steam and other
roads to be added when required for
future use
Eight tracks for steam railroads

PROPOSED NORTH RIVER BRIDGE—SECTION OF SUSPENDED SUPERSTRUCTURE.

"PRESERVALINE," A NEW PRESERVATIVE FOR MEAT.*

By Dr. BRUNO TERNE.

SOME time ago I was applied to for information as to how to pickle meat without the use of nitrate of potash or saltpeter. The objections to the use of saltpeter are said to be:

(1) The operation of curing takes too long a time.

(2) It renders the outside of the meat hard.

"There is a compound," my inquirer said, "that is used in large quantities in the West, and which avoids both these objections. What is it?"

I informed him that if he would procure me a sample of this material, or would, in lieu of this, furnish me either with a specimen of meat prepared with it, or with some of the pickle as prepared for use, I might be able to throw some light upon the subject.

Shortly after this, I came into possession of two samples, both in pulverulent form, one red and the other white in color. I exhibit specimens of both of these preparations. From another source I learned that this product was placed on the market under the trade name of "Preservaline."

A qualitative test showed conclusively the absence of all nitrates and the presence of boracic acid in combination with a base, for the reason that the characteristic green coloration of the flame only appeared after the addition of a drop of sulphuric acid. It appeared further that both the red and white samples had the same composition, with the sole difference that to the colored sample there had evidently been added some rosanilin color.

I made up a sample with a little rosalic acid which exhibited nearly the same color as the original one but a little more pronounced.

The quantitative analysis of the white sample gave:

	Per cent.
Biborate of sodium	44·18
Chloride of sodium	45·30
Moisture	7·80
Impurities (undetermined)	28·2
	100·00

Practically, then, we have here a mixture of equal parts of borax and common salt, and the "regular" preservaline, which imparts to the meat a cherry red color, as per announcement of the manufacturers and vendors of this article, is simply the same product, with the addition of some coloring matter or dye.

I was aware that the use of coloring matters was largely employed in certain articles of food, especially in all candies and cakes, and the like, but it was somewhat of a surprise to learn that enterprise in this direction had progressed so far as to impose dyed meat upon us.

I investigated the red sample for traces of arsenic, which possibly might be contained in the color, but I am glad to report that I found none.

The solution of both samples was strongly alkaline. Without any doubt, this product, on account of the large quantity of borax in its composition, will act as a good preservative, but it is unquestionably a fraud upon the public, so far as the selling price is concerned, as the following statement will show:

	Cents.
One pound of borax is worth	9
One pound of salt is worth	1½
Two pounds of mixed salt is worth	10½
One pound of mixed salt is worth	5¼

It is put upon the market for the prices indicated in the following tabulation, reproduced from the manufacturers' circular:

"REGULAR."

For Curing Pork and Beef.	Per Pound. Cents.
In barrels	14
100 lb. kegs	15
50 lb. drums	16
25 lb. drums	16
10 lb. box	16

Use one pound for every 100 pounds of meat.
This preservaline gives the meat a cherry red color.

"A."

For Pork and Liver Sausage.	Per Pound. Cents.
In barrels	24
100 lb. kegs	25
50 lb. drums	26
25 lb. drum	26
10 lb. box	26

Sprinkle one-half pound over every 100 pounds of meat while being chopped or mixed.

"B."

For Bologna and Smoked Sausage.	Per Pound. Cents.
In barrels	16
100 lb. kegs	17
50 lb. drums	18
25 lb. drums	18
10 lb. box	18

Use one pound for every 100 pounds of meat.
Preservaline prevents any kind of sausage from turning sour, even in the warmest weather, and retains the natural color of the sausage.

Looking over the literature of the subject, I found that a series of investigations of similar products had been made by Mr. G. Polenski (*vide Reports of the Imperial German Health Office*, 1889, No. 5, p. 364).

I quote therefrom the following data, respecting the composition of a number of such materials.

* Read at the meeting of the Chemical Section of the Franklin Institute, May 19, 1891.

(1) THE REAL AUSTRALIAN MEAT PRESERVER.

(A nearly colorless liquid, emitting a strong odor of sulphurous acid.) It contains in one liter:

	Grammes.
Calcium oxide	11·080
Sulphurous acid	46·080
Ferric oxide (alumina)	0·039
Silicic acid	0·052

(2) REAL AMERICAN MEAT PRESERVER.

(The same liquid, but a stronger solution.) Contains per liter:

	Grammes.
Calcium oxide	26·42
Sulphurous acid	89·60
Ferric oxide (alumina)	1·80
Silicic acid and alkalies	1·20

(3) CONSERVATIVE FOR SAUSAGES.

(The same liquid, slightly opaque, but odorless.) Contains per liter:

	Grammes.
Saltpeter	33·40
Boracic acid	27·50
Glycerine	50·00

(4) PRESERVING SALT OF R. LEISENTHAL, COLOGNE.

(Does not redden the meat.)

Borax	48·40
Water of crystallization	39·00
Common salt	3·44
Sodium bicarbonate	9·10

(5) PRESERVING SALT OF THE SAME MANUFACTURER (TO MAKE THE MEAT RED).

	Per Cent.
Boracic acid	28·34
Common salt	9·58
Saltpeter	57·35
Water	4·50

(6) PRESERVING SALT OF GAASE BROS., BERLIN.

	Per Cent.
Boracic acid	29·70
Saltpeter	37·80
Common salt	26·70
Water	5·80

(7) AMERICAN HAM PRESERVER.

(An acid, yellowish liquid, having an empyreumatic odor.) Contains per liter:

	Grammes.
Potash alum	70·00
Saltpeter	31·04

(8) STUTTGART CONSERVING LIQUID FOR MEAT.

(An acid liquid, having a strong sulphurous acid odor and a yellowish color.) Contains per liter:

	Grammes.
Arsenious acid (As_2O_3)	0·103
Common salt	5·500
Phosphate of lime ($Ca_3(PO_4)_2$)	41·940
Sesquioxide of iron and alumina	0·440
Sulphurous acid	37·440
Free phosphoric acid (H_3PO_4)	6·050

(9) SIMPLE CONSERVING SALT OF CONSERVING SALT CO., HAGEN.

(A white salt, in solution, alkaline.) Contains:

	Per Cent.
Borax	21·95
Water of crystallization	13·30
Saltpeter	33·10
Common salt	33·04

(10) TRIPLE CONSERVING SALT OF THE SAME MANUFACTURER.

	Per Cent.
Salt	0·80
Boracic acid	55·50
Borax	29·00
Water of crystallization	14·70

(11) SAZOLITH.

	Per Cent.
Sulphate of soda	37·3
Sulphurous acid	39·7
Soda	21·0
Water	2·0

(12) BERLINIT.

	Per Cent.
Common salt	7·5
Boracic acid	9·0
Borax	83·7

BERLINIT PICKLE (for reddening the meat).

	Per Cent.
Salt	45·9
Saltpeter	32·2
Boracic acid	19·2
Water	2·0

(13) CHINA PRESERVING POWDER (MINERVA).

	Per Cent.
Common salt	25·00
Boracic acid	17·7
Sulphate of sodium	38·8
Sulphite of sodium	9·2
Water	9·3

(14) AUSTRALIAN SALT.

	Per Cent.
Common salt	5·5
Borax	94·0
Hydrocarbon (?)	0·5

(15) DR. C. RUEGER'S BARMENIT.

Equal parts of borax and common salt.

This last brings us home again. American ingenuity, it will be perceived, is again in the lead. All the liquids and powders here referred to are free from coloring matter. They all use saltpeter to impart the red color to the meat, but the inventor of preservaline introduces the novelty of a dye to take its place.

The directions given by the manufacturer for the use of the red "regular" for curing pork and beef prescribe one pound for every 100 pounds of meat. This is equal to one-half per cent. of borax.

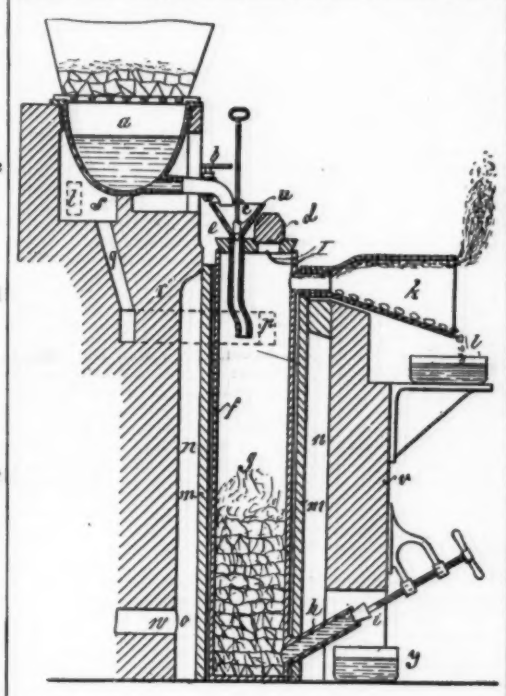
The prescription for the white, for curing bologna and smoked sausages, indicates the same quantity.

We have no positive knowledge of the action of large quantities of borax upon the human organism, when taken internally, though there can hardly be any doubt that if taken even in small doses continuously for a considerable time its effect must be hurtful. This question, however, I leave to the decision of others better qualified for passing judgment upon it than myself. It was simply my intention to call to your notice the common use of borax as a preservative for meat, and especially the misuse of aniliin red to replace in such mixtures the use of saltpeter.

IMPROVED PROCESS OF MAKING SODIUM OR POTASSIUM.

THE author of this process is Curt Netto, of Dresden, Saxony, Germany. The drawing is a vertical sectional view. *a* represents the reservoir used for melting the caustic soda, the outlet pipe of which is provided with a regulating faucet, *b*.

c is the charging funnel for the molten caustic soda, which leads through the lid, *e*, the latter being provided with a charge hole, I, for the coal into the retort, *f*, made of proper material—*i. e.*, cast steel, wrought or cast iron—and wherein the reduction should take place under the influence of the coal, *g*. The tap pipe, *h*, arranged near the bottom of the retort, is properly provided with a valve, *i*. In an opening at the upper part of the retort a receiver, *k*, somewhat narrow, is properly arranged for condensation of the sodium. Under the outlet of this condenser is placed a reservoir, *l*. The retort, *f*, is covered with a jacket, *m*, of clay. The gases used for heating are led through the flue, *w*, and opening, *o*, into flue, *n*, where they circulate around the retort. Then the gases pass through the opening, *p*, flues, *r* and *q*, into



the heating space, *s*, where they heat the vat, *a*, and now they can be led off through opening, *t*, into the chimney. The charging funnel, *c*, can be provided with a conical valve, *u*. Below the tap pipe, *h*, is placed a receiving vessel, *y*, for the molten mass of soda formed during the reduction.

By means of such apparatus the present process is executed in the following manner: The retort is heated to about cherry red, then it is charged by either taking off the lid, *e*, or through the charge hole, I, with as much coal, preferably charcoal, as will fill about one-third of its capacity. When the coal is glowing (a few minutes are sufficient for the purpose), the molten caustic soda is allowed to run from the vat, *a*, through the funnel, *c*, upon the glowing coal. The flow can be regulated by the faucet, *b*. Immediately the sodium flame becomes visible at *k*, and after a very short time the sodium flows off from *k* into the reservoir, *l*. In the beginning it is necessary to close the valve, *i*, in order to keep off the atmospheric air; but in a short time, about half an hour, enough liquid mass, the greater of which is carbonate of soda, will have gathered at the bottom of the retort, so as to form at *h* a hydraulic closure, and now the valve, *i*, can be opened, whereupon any excess of molten mass can freely flow off through the tap pipe, *h*. When after some hours the stock of coal in the retort is nearly exhausted, the flow of caustic soda is cut off by closing the faucet, *b*, and after waiting some minutes, until the sodium flame at *k* has nearly disappeared, fresh coal is charged in through I, whereupon the operation recommences after having closed the opening I, which can be done, for instance, by simply placing upon it an iron cylindrical plug. It is obvious that the introduction of coal may be effected in any way—*i. e.*, as in charging gas generators—in order to completely avoid opening the retort for charging coal. It is not necessary to fasten the lid, *e*, by screws or wedges. It is sufficient to simply lay it in place. Any other carboniferous material may just as well be employed for the decomposition; but charcoal offers a special advantage on account of its containing a low degree of silicic acid and a comparatively high degree of alkali in its ashes. On account of the absence of silicic acid stubbornness of the liquid mass is avoided, and by reason of the comparatively high degree of alkali in its contents the losses of alkali become comparatively small, notwithstanding the unavoidable sodium flame. The mass can be separated from particles of coal contained in it by lixiviation and the solution can be worked to carbonate of soda or regenerated into caustic soda.

Among the advantages obtained by the present process are the following:

The process is carried on at a comparatively low temperature, *i. e.*, cherry red heat. Disadvantages of horrizontal retorts and sagging of the same are avoided. Danger of explosion is avoided, as the quantity of the soda introduced can at all times be regulated by the position of the faucet, *h*, or completely shut off. Should the pressure in the retort by any reason become too high, the iron plug, *d*, at I operates like a safety valve, so that the gases can freely escape.

The evacuation of the retorts and the charging of the same, the fixing of the lids on the hot retorts during the operation, are not necessary. By a simple closing off of the faucet in the alkali supply pipe the action ceases by itself after one or two minutes.

The process admits of the use of less valuable products containing soda, *i. e.*, the bottoms, the use of which has heretofore been economically impracticable, as the charge had to be held concentrated as much as possible. The present process admits of a continuous operation with all its advantages.

ROLLING FLUID METAL.

ON THE MANUFACTURE OF CONTINUOUS SHEETS OF MALLEABLE IRON AND STEEL DIRECT FROM FLUID METAL.*

By Sir HENRY BESSEMER, F.R.S.

AMONG the numerous inventions that are from time to time brought under public notice, a certain proportion are from some cause or other allowed to fall out of sight and be forgotten. This too frequently happens from some inherent defect or fallacy involved in the scheme itself. It is not, however, always the cause, for some inventions, which appear well worthy of a trial, are never put to any practical test, through having appeared at a time when the state of the particular manufacture to which they apply was not so far advanced as to render the proposal feasible with the then existing state of knowledge, although at a later period, and a more advanced state of the arts, they would at once have been adopted. Hence it has occurred to me that an invention in connection with the iron and steel manufacture which has quietly slept in oblivion for the last thirty-five years might with advantage be discussed at a time when the manufacture of tin plates is occupying so much public attention. I have nevertheless felt much hesitation in venturing on this innovation, which need not be made into a precedent.

Before entering into any details of the method proposed for the production of continuous sheets of iron or steel, it may be interesting to glance briefly at some analogous processes which have been proposed, and in some cases have been carried into successful operation. In doing so the mind naturally reverts to that period when sheets of paper, like our present tin plates, were all made singly by hand. The paper maker with a square gauze wire sieve dips it into a cistern of pulp, and afterward holds it horizontally above the cistern until the water gradually drains out of it; he then transfers the fragile film of pulp to a surface covered with flannel, on which he leaves it to dry and harden. But the great invention of Fourdrinier, as improved by Donkin, has given us a marvelous self-acting machine, having a cistern of pulp at one end, with an endless wire gauze sieve delivering its film of pulp on to a flannel-covered drying roll, and from thence on to steam-heated glazing cylinders; the machine terminating with a wooden roller, on which an endless web of paper, a mile long, is wound up, fit for any of the varied purposes to which that beautiful material may be applied. This result is accomplished with a rapidity of action, an economy of material, and an excellence of quality that has revolutionized the whole paper trade of the world.

The production of continuous sheets of different materials, direct from fluid or semi-fluid matter, occupied much of my attention a great many years ago; and as far back as the year 1846, I took out a patent for the production of tinfoil and sheet lead direct from the molten metal.

The form of apparatus proposed comprises an iron tank, covering the upper part of the furnace. This tank can be used both for melting the metal and for retaining it in a fluid state during the rolling operation. A shaft crosses the tank, and carries a hollow segment of a cylinder; and by means of a screw and wormwheel, a slow rotation is given to the shaft, thus slowly and regularly immersing the segment, and thereby displacing and raising the level of the metal in the tank, and causing it to flow between a pair of rolls where the metal is chilled, and is converted into a sheet, dependent for its thickness on the distance apart of the rolls, from which it descends on a curved guide plate. The rolls are kept cool by a constant current of water passing through them. I may mention that this invention was included in a patent for the manufacture of glass, and, as far as I know, this particular form of apparatus has never been put to any practical test. I may also add that I received, about two years ago, a parcel from America containing a small sample of sheet metal, which was being successfully manufactured there. The person from whom I received it informed me that it was made by a slight alteration or improvement on my patent of 1857, for rolling continuous sheets and thin bars of iron or steel direct from the fluid metal. He offered me one-half of his patent if I would undertake its introduction into this country. I did not accept his offer, and there the matter rested.

The circumstances stated have, however, afforded me an opportunity of showing you a small sample of a continuous sheet, produced direct from fluid metal at a single operation, and proves beyond doubt or question the important fact that fluid metal may be chilled and formed into a continuous sheet between rolls that are kept cold, while it well illustrates the spirit of enterprise of our American cousins, who are so prompt

* Paper read before the Iron and Steel Institute.

to recognize, to adopt, and to improve upon the inventions brought forward in Europe.

In the year 1846 I commenced a series of experiments on the manufacture of continuous sheets of glass. The first rough experimental apparatus which I used may be described as follows: It consists of a reverberatory furnace, in which a deep bath or cistern is formed, and is used in lieu of the large glass pots previously employed for melting all kinds of glass. The bottom of the bath is sloped or inclined to one side where there is a long parallel opening, having a projecting lip; the lower side of this lip in part overhangs one of the rollers. During the time that the glass materials are being melted the opening is closed with an iron bar resting on the lower lip; on the removal of this bar the semifluid glass moves slowly out of the bath, and by the rotation of the rolls is converted into a thin sheet, and then descends the curved guide plate, and is finally received on a horizontal bed.

The rapidity with which a thin sheet of glass passes from a soft and plastic state to one of extreme brittleness is peculiar to this material, and presents a great difficulty in its manufacture, a difficulty which is much increased by the rapidity with which the sheet is produced, and which will be readily appreciated when I state that on one occasion a sheet of glass 70 feet long by 30 inches wide was produced in about three or four minutes, the first portion having become hard and brittle while the latter portion still retained its plastic state. Fortunately both iron and steel, after passing from the fluid to the solid state, still retain their malleable condition, and give ample time for further treatment before they become cold.

Having thus briefly brought under your notice what has already been accomplished experimentally in the direct production of continuous sheets of lead and glass by the process of rolling, I will pass on to that branch of the subject which is more immediately interesting to the members of this Institute, many of whom may remember that in August, 1856, I first announced to the world the fact that malleable iron in a molten state could be produced rapidly, and in large quantities. It is not surprising that I should have at once endeavored to avail myself of the advantages which this novel condition of fluidity presented. I saw, of course, that like other fluid metals, malleable iron could be cast in moulds into any desired form, and reverting to my former inventions for rolling fluid lead and glass into continuous sheets, I at once grasped the idea that malleable iron or steel could be thus made not only into sheets and plates, but also into thin bars or rods, by passing the fluid iron in between a pair of rolls placed in the same horizontal plane.

I was most anxious to bring to the test of experiment a system so novel, and so immensely important if successful.

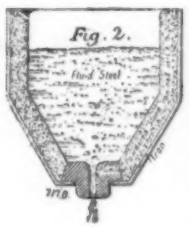
At the period mentioned I was carrying on a secret process of manufacturing bronze powder at my works at St. Pancras, where I was also making my iron and steel experiments; and in the bronze works I had in daily use a pair of 12-in. chilled rolls placed in the horizontal plane. I saw at once that these rolls would enable me to make such a trial of the scheme as would prove the possibility or otherwise of producing a continuous sheet direct from fluid iron. Unfortunately these rolls were working at some distance from the model converting house, and in a room that was carefully locked and guarded; and into which no strange workmen could be permitted to enter. I therefore had to depend entirely on myself for these experiments. I employed a common 20 lb. crucible as a converter, and after melting 6 lb. or 8 lb. of pig iron in it, I immersed the orifice of a fireclay blow-pipe in the metal, which was by this means wholly decarbonized. No manganese or spiegel was added to it.

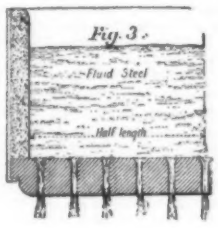
I then seized the crucible in a pair of tongs and ran with it into the bronze works. This naturally took some little time to accomplish, and when I arrived at the rolls the metal in the crucible had assumed the solid form, and could not be poured out. After several unsuccessful attempts I at last succeeded in reaching the rolls with some fluid metal. The crucible was lifted on to the back roll, and the molten iron was poured in between them. The rolls were set at about $\frac{1}{20}$ in. apart, and a thin sheet was obtained some 3 ft. or 4 ft. in length. The small stream from the crucible did not spread itself far along the wedge-shaped space between the rolls, and as the quantity poured fluctuated a little, so the breadth of the plate increased or decreased in the same ratio, giving an undulating line to the edges of the plate, some portions of which were afterward rolled to a thinner gauge.

The sheet thus produced had a clear surface, almost wholly free from oxidation, and absolutely free from scale. It was as tough as any rolled iron plate I had ever seen; indeed, it left no doubt in my mind of the entire success of this system of rolling thin sheets direct from fluid metal.

The thin plate was cut into small samples, and given to different persons. The only relic now remaining of it is a small piece among other early examples of Bessemer metal, contained in a glass case at the offices of the Institute, where this small piece of the original plate may be seen.

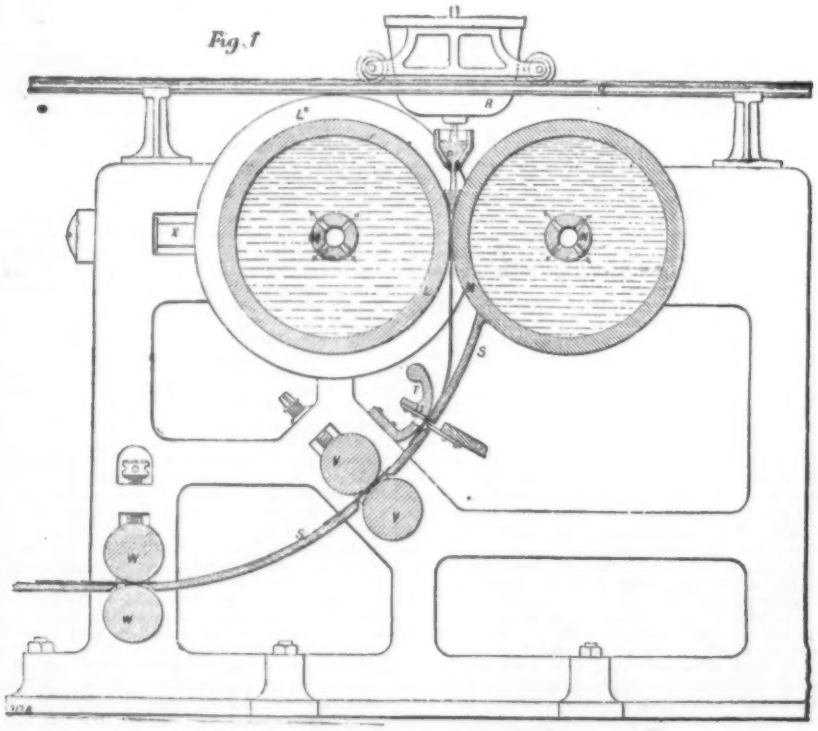
So impressed was I with the importance of this invention, that I immediately applied for and obtained a patent for it, notwithstanding at this particular time the Bessemer process was not merely under a cloud, but was regarded by the trade generally as an absolute failure. One need not, therefore, be greatly surprised that the production of continuous sheets direct from fluid iron did not excite a great amount of enthusiasm in the minds of tin plate manufacturers of that day; in fact, the whole scheme was simply poohpoohed and laid aside, without any serious consideration of its merits.





It is under these circumstances that I have ventured to occupy your time with a chapter of ancient history, in the hope that with the much greater knowledge and skill since acquired in the production and manipulation of mild steel, this system of producing continuous sheets of metal may have the thoughtful attention of those interested in the tin plate manufacture.

I will now describe, in as brief a manner as possible, the apparatus hurriedly secured by patent immediately after this experiment was made. It consists of a pair of rolls, through which cold water is made to circulate; and for their more effectual cooling perforated pipes are provided for throwing jets of water against the exterior surface of the rolls; a pair of rubbers kept in contact with the rolls by spiral springs are employed for the purpose of drying the surface of the rolls; it will be observed that one of the rolls has formed on it a flange at each end, between which flanges the other roll is closely fitted, so as to form a stop at the end of the rolls, and converts the space between them into a small wedge-shaped trough, into which the fluid metal is poured from the lip of the casting ladle. The rolls are not held up to their work by screws as usual, but the brasses of one of them are fixed, while the brasses of the other roll slide in suitable guides, and are kept in the required position by a weighted lever, so that in the event of too much metal being at any time supplied to the rolls, they will be forced back, and the plate made a little thicker at that part, a defect easily remedied in the next operation of rolling, the giving way of the rolls thus acting as a safety valve and preventing a breakdown.



ROLLS FOR FLUID METAL.

I also designed a pair of grooved rolls for producing thin bars, capable of afterward being rolled into hoop iron, nail rods, etc.

From the foregoing brief sketch of my original form of apparatus, it will be seen that it would be very difficult to supply the molten metal to the rolls with that degree of regularity which is absolutely necessary, while more or less of the slag floating on the surface would be poured out simultaneously with the metal. It will also be observed that in this arrangement of apparatus the metal would fall only on one spot, and if wide sheets were being made, it would have to flow lengthwise along the rolls from this one central stream. A further disadvantage would result from the splashing and unquiet state of the metal between the rolls, owing to the great height from which the metal would have to fall from the lip of the large ladle placed high above them.

Having thus freely criticised my first imperfect form of apparatus, I will proceed to explain in what manner I now propose to remedy these defects. These suggested improvements will be readily understood by reference to Figs. 1, 2, and 3, annexed; and here I beg to observe that I have not gone into the many details necessary for the construction of rolling mills of this description, but have merely given such an illustration of the general scope of my proposals as will enable them to be understood.

The rolls, L and M, consist of two hollow drums through which a tubular steel axis, N N, passes, and conveys a plentiful supply of water for keeping the rolls cool.

The brasses which support the roll, M, are fixed, while those which support the roll, L, are movable in a suitable slide, and are pressed on by a small hydraulic ram, X, which is in free and uninterrupted communication with an accumulator, so that at any time should the feed of metal be in excess, the roll, L, will move back and prevent any undue strain in the machinery, the only result being a slightly increased thickness at that part of the sheet of metal, a defect which, as it extends parallel across the whole width of the sheet, will be easily corrected in the next rolling operation.

The rolls, by preference, may be made 3 ft. or 4 ft. in diameter, each having a flange on one end only, and thus form a trough with closed ends for containing the fluid metal.

In order to obtain a regular and quiet supply of metal, I employ a small iron box or reservoir, P, lined with plumbago or fireclay, along the bottom of this reservoir. Some ten or twenty small holes of about $\frac{1}{4}$ in. in diameter are neatly moulded by a row of conical brass pegs. The reservoir is provided with a long bar or handle at each end. By means of these bars the reservoir is supported on the side frames, the bars falling into suitable notches made in the roll frame for that purpose.

And here I would observe that the reservoir, P, should be well dried, and its interior surface heated to redness prior to its use. For this purpose a small furnace or stove should be placed near to the rolls, the stove having two or three rectangular openings on its upper side, in size corresponding to the interior of the reservoirs, which are to be inverted over these openings, the hot products of combustion passing freely through the row of holes, and bringing up the interior surface of the reservoir to a full red heat. In this state the reservoir is to be placed in its proper position in the roll frame, immediately after the arrival there of the ladleful of fluid metal.

A pair of rails, Q, are supported on the roll frames, and serve for the conveyance of the ladle, R, which is mounted on wheels, and brings the metal direct to the rolls, or to any number of pairs of rolls that may be placed in line.

The ladle is provided with one or more valves or stoppers of the usual kind, by means of which the supply of metal to the reservoir, P, may be easily regulated; the several small streams from the reservoir will deliver an almost constant quantity of metal, varying only slightly as the operator regulates the head of metal in the reservoir—a means of regulating which a little experience would allow him to utilize with great advantage; from the smallness of the head of metal in the reservoir the several streams will fall quietly without splashing. These streams do not fall direct on to the rolls, but into a small pool formed between the thin films, solidifying against the cold surface of the rolls, the metal at all times being free from floating slags.

The speed of the rolls also affords a means of regulating the quantity of metal retained between them; and as a pair of 4-ft. rolls would only require to make about four revolutions per minute, a quick-running engine could easily be provided with differential speed gearing, so as instantly to alter the speed of the rolls to the very small extent ever required during the rolling process.

The thin sheet of metal, as it emerges from the under side of the rolls, is received between the curved guide plates, S and T, to the latter of which a cutting blade, U, is bolted. Beneath the guide plate, S, a similar cutting blade is arranged to suddenly move forward by a cam and cut the thin sheet in two, the piece so cut afterward passing between the second pair of rolls, V V, from which it again descends by gravity, and passes between the third pair of rolls, W W, and is delivered on to a horizontal table, or it may be allowed to slide down the inclined end of a cistern of water, and moved slowly forward. By these means it will be possible to cool and stack a ton of plates without any labor or trouble.

The thickness of plates capable of being produced will much depend on the size of the rolls; if drums of 10 ft. or 12 ft. in diameter are employed, it is probable that plates of $\frac{3}{4}$ in. in thickness could be produced, or perhaps even thicker. The central space between drums of such large diameter would represent a sort of plate ingot mould with nearly parallel sides for some 8 in. or 10 in. in depth.

When producing sheets of steel, the initial thickness of which does not exceed one-tenth inch, it might at first sight appear that the finished plate, with only two more rollings, would not get sufficient work done upon it to develop the same degree of toughness and cohesion that would be obtained by the many rollings which the present system necessarily involves; but a little consideration will render apparent the entirely

different conditions under which the formation of the plates takes place.

Mild cast steel is a crystalline substance, and follows the inevitable law of all crystalline bodies, in so far as the size of the crystals depend on the bulk of the mass and the time allowed for their formation; the longer the time allowed, and the greater the mass, the larger are the crystals obtained; their planes of cleavage are also more clearly defined, and are more easily separated from each other, or, in fact, have a less amount of cohesion.

A cast ingot of 1 ft. square, quietly reposing in a soaking pit or heating furnace, may go on crystallizing for two or three hours, and develop a coarse crystalline structure, but, in rolling fluid steel in the manner proposed, we have, in place of a 10 inch ingot, a sheet of one-hundredth of that thickness only, and in lieu of the two or three hours allowed in ordinary cases for the development of crystals, we have, when using a 4 ft. pair of rolls, making four revolutions per minute, a transition from absolute fluidity to absolute solidity in just one-half of a second of time, in a mass of only one-tenth inch in thickness; and if crystals are developed at any period during the half second of time occupied by this transition, they must be microscopic indeed, and possess but little, if any, of the properties that are developed in large masses during hours of repose in the soaking pits; hence it appears to me highly probable that the homogeneous fluid metal will pass at once into a perfectly homogeneous uncrystalline body, and being subjected to fluid, semi-fluid, and solid pressure in rapid succession, will develop the full cohesive force and toughness which the metal is susceptible of.

It will be at once perceived that in this mode of disposing of a ladleful of steel in the rolls we avoid the cost and the wear and tear of casting moulds, and the labor of their removal and rearrangement at each casting operation, also the need for soaking pits or reheating furnaces, with their accompanying cost of labor and fuel. There will also be no loss arising from the waste ends of piped ingots, etc.

It will be understood that thin sheets so produced will not acquire any scale during the single minute they are exposed to the oxidizing influence of the atmosphere prior to their immersion in the water tank, and in consequence of there being no overlapping of plates in rolling there will be but little loss of metal in shearing.

With reference to speed of production, let us assume the mill to be fitted with a pair of 4 ft. diameter rolls, 18 inches wide, and making four revolutions per minute, and set to produce a sheet having an initial thickness of one-tenth inch, and rolled by the third pair to one-twentieth inch, we should thus have a surface velocity of the first pair of rolls equal to 50 ft. per minute, and making when finished 100 plates 18 inches by 12 inches, one-twentieth inch thick, and weighing 300 pounds, or equal to a production of one ton of plates in seven and a half minutes.

Hence it becomes a question which is the least costly mode of dealing with a ladleful of fluid steel—forming it into massive ingots in moulds or making it into thin sheets in the manner proposed?

KITE PHOTOGRAPHY.

FOR obtaining aerial photographs we can operate only in a free or captive balloon or by means of a kite. The latter method is evidently the less complicated and the simpler of the two, and, moreover, can be utilized by anybody. So the remarkable labors of Mr. A. Batut, recorded in this journal and in an interesting pamphlet, have led various persons to experiment in this new field so full of promise. Among those who, after becoming imbued with Mr. Batut's ideas, have tried to improve upon them, may be mentioned Mr. E. Wenz, of Reims, who has obtained some very interesting results, which we deem it our duty to make known.

Let us in the first place briefly recall the principal arrangements of Mr. Batut's apparatus in order the better to set forth those adopted by Mr. Wenz.

1. *The Kite.*—This has the form of a quadrilateral composed of two isosceles triangles. One of the diagonals is 2·5 meters in length and the other is 1·75 meter. The extremities of the frame are connected by a cord, and the whole is covered with paper strengthened with cloth at the angles.

2. *The Camera.*—This is a simple cubical box of whitewood blackened internally and covered externally with black paper. The objective is placed upon one of the sides, and upon the opposite side, which is movable, may be fixed the sensitive preparation—plate or film.

3. *Method of Suspending the Camera.*—As a result of the studies made by him, Mr. Batut admits as a principle that the camera should form part and parcel of the kite. To this effect he employs a triangular support which is screwed just above the center of the main rib. In order to completely free the field of the objective, Mr. Batut uses a double support that carries a bar, from the extremities of which start two cords that unite to form the principal cord.

4. *The Shutter.*—This is a simple guillotine placed in front of the objective and operating through a touch-wood slow match lighted at the start.

5. *The Reel.*—This consists of a wooden bobbin provided at each end with a winch.

Let us now examine, in the same order, the various parts of the Wenz apparatus. In this way, the modifications introduced will at once strike the reader without the necessity of dwelling on the subject at length.

1. *The Kite.*—Mr. Wenz adopts the dimensions fixed by Mr. Batut, but he has, on the contrary, endeavored to render the apparatus capable of being taken apart, and to give it less weight. To carry a kite of so large a size, in fact, is not an easy thing to do, provided that

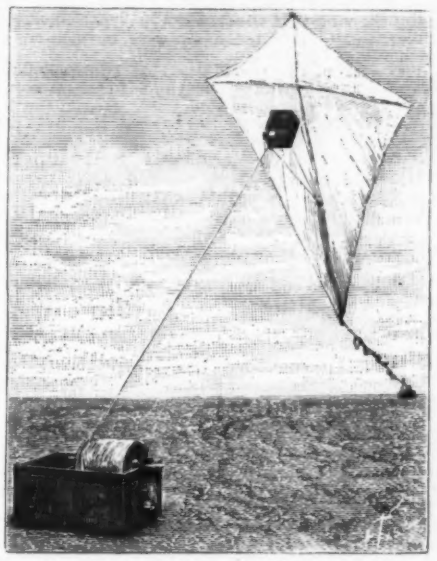


FIG. 2.—WENZ'S PHOTOGRAPHIC KITE.

there is some little wind. So that the advantage that the operator will find in mounting it only at the place desired will be easily understood. To this effect two copper tubes of the same diameter are brazed together in the form of a cross. Into each of these tubes is inserted a bamboo rod provided (like fishing rods) with copper ferrules. These rods have the following dimensions: 2 meters, 0·5 meter, and two of 85 centimeters. The skeleton of the apparatus is, therefore, cross shaped. The extremities of the rods are connected with each other by means of a cord. The whole supports a canvas covering connected with the extremities of the rods by strong pockets. Small cords placed here and there are fastened around the rods and maintain the whole. This very simple arrangement, as may be seen, permits of quickly mounting the kite and taking it apart.

2. *The Camera.*—Mr. Wenz employs wood and cardboard cameras, either of the size $11 \times 15\frac{1}{2}$ or 18×24. The first is provided with a simple objective, and the second with a large angular one. The mountings of the objectives are of aluminum.

3. *Method of Suspension.*—After trying the arrangement recommended by Mr. Batut, the author was obliged to discard it, on account of various inconveniences that he discovered.

It is difficult, in the first place, to construct a support for the camera which shall be both light and sufficiently rigid; and, on another hand, on account of the very arrangement that renders the kite and camera interdependent, the apparatus is obliged to constantly follow the motions of the kite around its axis. And then, despite the special arrangement of the bar, it frequently happens that the cords get into the field of the objective.

Mr. Wenz recommends another method, which consists in suspending the camera at pleasure in the support. The latter, in fact, undergoes none of the rotary motions of the kite around its axis. The camera, so to speak, thus takes the place of the bar with a point of attachment on each side, so as to permit of easily modifying its inclination.

This arrangement presents the following advantages: 1, entire suppression of the camera support adherent to the kite; 2, the field of the objective completely free; 3, surface of action of the wind slightly increased; 4, suppression of the bar; 5, regulation at will, and easy inclination of the camera, from the perspective view behind. We call particular attention to the latter point, which is a capital one. In fact, although it is of interest to take the topography of the field beneath the kite or in front of it, it may be still more useful to reproduce the entire zone behind the apparatus.

There may thus be obtained data as to pieces of ground not accessible to the operator.

5. *The Shutter.*—Mr. Wenz places the shutter, which is merely a simple guillotine, in the interior of the objective. He thus obtains a slight reduction of weight and especially of bulk. The shutter is operated by a touch-wood slow match, as in the Batut system, or by a second cord, which permits of operating at the desired moment.

6. *The Reel.*—Mr. Wenz, having the intention of making experiments at heights exceeding 1,000 meters, has endeavored to combine an arrangement to permit him to wind up the cable rapidly, so as to shorten this operation as much as possible. The reel, carrying 2,000 meters of cord marked at every 25 meters, is so supported as to allow it to revolve freely. One of the ends carries a thick rubber which is in contact with a cast iron wheel mounted upon the box of the windlass, and which is actuated externally by means of a winch. The diameter of this wheel and that of the rubber disk is so calculated that six revolutions of the reel may be obtained for one revolution of the winch. The winding may thus be done very rapidly. The box that supports the reel is so arranged as to contain all the *materiel*—camera, plates, reel, and the covering of the kite, but not the mountings, which are carried in the hand. It contains likewise a sort of tent of black cloth, which permits of using it for changing the sensitive preparations.

As may be seen from this description, Mr. Wenz's *materiel* is well conceived and presents a perfectly studied system as a whole. We have in hand some excellent negatives obtained with this apparatus, and they are as remarkable for their execution as for their size. Several of them are 18×24 centimeters in dimensions. We reproduce one of them in Fig. 1. Fig. 2 shows the kite with the camera and its support. It is directed in such a way as to take a perspective view behind. In this position, the extremity of the kite will be in the field of the objective, but in all other positions the latter will be entirely free. Fig. 1 reproduces a portion of an 18×24 photograph obtained under such circumstances. It represents the coast of Berck-sur-Mer. The photograph possesses a sharpness that could not be reproduced in an engraving. The view was taken at a height of 305 meters. Mr. Wenz calculated this height by measuring one of the buildings reproduced upon his negative and the dimensions of the same object upon the latter; a being this first measurement, and b the second, we have $\frac{a}{b} = \frac{x}{f}$:

x is the height sought, and f the focus of the objective, and we then have $x = \frac{a \times f}{b}$

In closing, it seems of interest to state that Mr. Wenz has succeeded in constructing apparatus of extreme lightness, and in thus realizing a great progress upon what has hitherto been done.—*La Nature.*

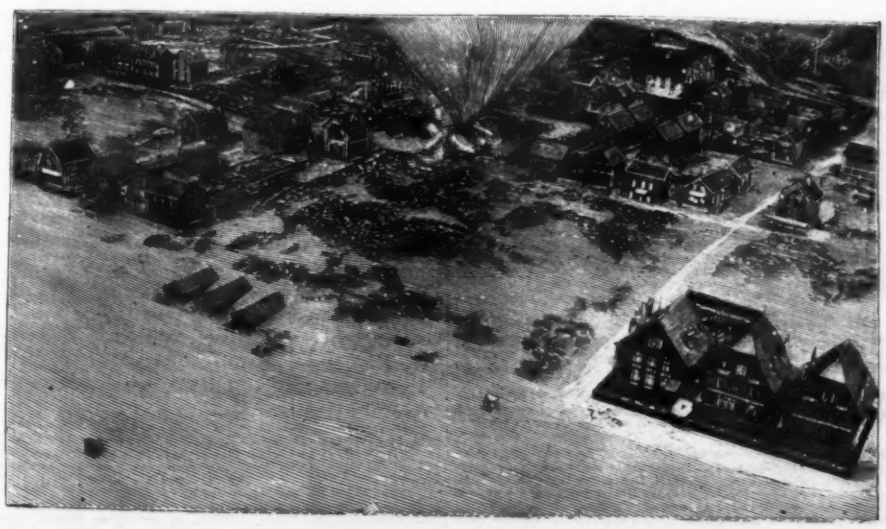


FIG. 1.—REPRODUCTION OF A KITE PHOTOGRAPH.

[Continued from SUPPLEMENT, No. 826, page 13198.]

PHOTOGRAPHIC CHEMISTRY.*

By Prof. R. MELDOLA, F.R.S.

LECTURE III.

THE photochemical studies which have been dwelt upon in the last lecture lead up to the consideration of the silver compounds, which must of course receive special treatment on account of their present importance in photographic processes. The broad facts that silver nitrate darkens on exposure to light when in contact with organic matter, that the silver haloids become colored when exposed under suitable conditions, and that other salts of silver, both inorganic and organic, also darken on exposure, will form the experimental basis from which the student may be led to the further consideration of the subject. At the outset of this work it is desirable to point out that our knowledge respecting the action of light on the silver compounds is in a different position to that concerning the simpler cases of photochemical decomposition which have hitherto been discussed. In the latter the chemical change is definite enough to be represented by ordinary equations, the composition of the final product being in most instances known. In the case of the silver salts we possess no such accurate knowledge, and the nature of the products is still surrounded by mystery.

When light falls on the silver haloids chemical decomposition takes place, accompanied by a change in color. In order that this statement may be properly realized, let it be shown that there really is decomposition, and that the chloride and bromide under these circumstances give off a gas which blues starch and potassium iodide paper. † The iodide does not undergo decomposition on exposure except in the presence of an iodine absorbent, *i. e.*, a sensitizer. From these facts a good lesson can be conveyed concerning the general nature of the action of sensitizers. Passing on to the action of light on films of the haloids, it is possible, by means of a few simple experiments, to demonstrate many important properties of these compounds with which the student should be familiar. For this purpose sheets of paper, well coated with the pure haloids free from excess of silver nitrate, and a few ordinary reagents, are the only requisites. By one operation it can be shown that with the same exposure the

* Lectures before the Society of Arts, London, 1891.—*From the Journal.*

† "Chemistry of Photography," pp. 62-66.

chloride becomes darker than the bromide and the latter darker than the iodide, and at the same time that reducing agents and halogen absorbents accelerate, while oxidizing agents retard the decomposition. Thus three strips coated respectively with the three haloids may be painted with stripes of solutions of (1) sodium nitrate, (2) sodium sulphite, (3) silver nitrate, (4) mercuric nitrate, (5) potassium dichromate. After exposing these strips simultaneously to the action of light, the stripes 1 and 2 will be darker than the ground color, showing the accelerating action of the reducing agents, 3 will also be darker than the ground color, showing that a halogen absorbent may also act as an accelerator without necessarily being a reducing agent, while 4 and 5 will retain the original color of the haloid, showing the retarding action of oxidizing agents. A comparison of the ground color in the three strips will also serve to show the different colors of the products of the photochemical decomposition.

Such demonstrations as these cannot fail to impress the mind that the action of light on the silver haloids is a distinct case of photochemical decomposition, but it is necessary at this stage to issue a caution. The action is in these cases continued up to the point of visible darkening, whereas in the photographic film the exposure is so short that no directly visible effect is produced. It must be enforced, therefore, that in associating the photographic image with these darkened products we are drawing largely upon arguments from analogy, and although I personally am inclined to the opinion that the products are the same in both cases, this view cannot be taught as a dogmatic truth in the present state of knowledge, for however probable it may appear for analogy, it must not be forgotten that in the way of direct proof there is still a gap which must be bridged over before the identity of the products can be taught as an established fact. But the full consideration of this question is better deferred till the photographic film itself comes to be dealt with The point that will now present itself is the actual composition of the darkened products, and here it may at once be pointed out to the student that our knowledge respecting these compounds is in precisely the same state as that concerning the colored haloids dealt with in the last lecture. In the case of the darkened chloride, it has been proved that this product contains a little less chlorine than the normal chloride.

In all three haloids, no matter how long the exposure may be, the final product always contains an enormous excess of unaltered haloid. It may safely be asserted that these products are not chemical compounds in the ordinary acceptation of the term, since they are not composed of the haloid combined with the colored product of photochemical decomposition in definite molecular proportions.* Neither can the "photosalts" be classed with definite "molecular compounds" of modern chemistry, since the latter also consist of substances combined in the definite molecular proportions, and can be more or less readily resolved into their constituent molecules by appropriate treatment. But the "photosalt" cannot be resolved by any such treatment, since all solvents which dissolve the normal haloid appear to decompose the darkened product, leaving only a trace of metallic silver. On the other hand, metallic silver cannot be extracted from the "photosalt" by any of the ordinary methods.

In answer to the question which the inquiring student would naturally put, what is the photosalt, it can only be said that these products must be regarded as indefinite molecular compounds of the silver haloids with colored unstable products of photochemical decomposition, the composition of the latter being as yet unknown. That the colored products are unstable appears from the fact that they cannot exist apart from an excess of the normal haloid. In the same way that a solvent will take up a solid till the point of saturation is reached, so the silver haloid, on exposure to light, becomes decomposed up to a certain point, *i. e.*, the point when the haloid is saturated with the colored product of photodecomposition.† Beyond this point the action of light produces no further effect unless a reducing agent is present capable of combining with the liberated halogen as fast as the latter is liberated. It is advisable to let the student observe for himself that silver iodide prepared with excess of potassium iodide undergoes no change of color on exposure to light, but that in the presence of silver nitrate or reducing agents, darkening occurs. Let him observe also that the darkened chloride yields no appreciable quantity of silver to dilute nitric acid, but that in the presence of a strong reducing agent, even when the latter is gaseous, such as hydrogen, the reduction may proceed up to the complete liberation of the metallic silver. This last point can be demonstrated very conveniently by placing some finely divided silver chloride (prepared by precipitation) into a glass tube through which a current of moist hydrogen is kept passing, the gas being made to bubble through a solution of silver nitrate containing free nitric acid. On exposing the contents of the tube for some time to strong light, silver chloride is precipitated from the solution of the nitrate, the chloride in the tube (which should be shaken from time to time in order to expose fresh portions) gradually becoming dark colored. An equal quantity of the chloride may be exposed in air at the same time for comparison. The two lots of darkened chloride are then treated with equal quantities of dilute nitric acid, the clear solution filtered off, and the filtrates tested for silver. If the experiment has been properly conducted, the solution from the chloride darkened in hydrogen will be found to contain distinct traces, while that from the chloride darkened in air will be free from silver. It is hardly necessary to point out that the chloride used in this experiment should be free from excess of silver nitrate, *i. e.*, prepared with an excess of a soluble chloride or chlorhydric acid.‡

Having arrived at the conclusion that the silver haloids, when exposed to light under suitable conditions, lose a small quantity of their halogen, and become converted into colored compounds, the course of instruction will here naturally diverge along two lines:

(1.) The nature of the colored product combined with the excess of unaltered haloid; and

(2.) The part played by the associated substance or sensitizer.

With regard to the first, it must be pointed out that although we have no positive information of a conclusive character, many views have been advanced, which are more or less worthy of consideration, and an excellent exercise in the use of scientific judgment might be given to the advanced student, by submitting the current notions respecting the composition of these products, and requesting him to prepare a critical essay embodying his own views. Although no definite conclusion might be arrived at, the exercise cannot fail to be of value as an educational test, not only by compelling the student to refer to original papers, but also as calculated to bring out any originality he may possess in the way of devising new crucial experiments—the highest criterion of competence as a technologist. Respecting the view that these compounds contain metallic silver, the fact that the chloride darkens under nitric acid may be taken as evidence to the contrary.* The discussion of the possibility that sub-haloids are present will link this part of the subject on to the purely chemical considerations dealt with in the last lecture. The possibility of the colored products containing oxygen, *i. e.*, being of the nature of oxyhaloids, is also worthy of being entertained.† In favor of this view is the analogy of cuprous chloride, which darkens only in media which can supply oxygen and which under these circumstances apparently forms an oxychloride. In the same sense may be interpreted the distinct sensitizing action of water already referred to. On the other hand, it may be pointed out that the chloride darkens in a high vacuum (*i. e.*, in the presence of mercury vapor), and under liquids such as pure benzene, petroleum, and carbon tetrachloride, which contain no oxygen, and which have previously been dried by chemical methods. The question thus assumes the form, whether the nature of the colored products may not vary in different media; whether, in easily halogenized liquids, such as benzene, the reduction might not be analogous to that which occurs in hydrogen; whether, in other cases, the unsaturated silver haloid residue may not form a colored compound with the organic product, and so forth. It may be pointed out that such questions as these open a wide and interesting field for experimental investigation.

With regard to the second point—the action of the substance associated with the silver haloid—it is legitimate to connect this action with the ordinary chemical processes with which the student has been familiarized. He has been taught that reduction and oxidation are concurrent in ordinary chemical reactions, such as when a silver salt is reduced by a ferrous salt. The principle can now be extended to photochemical reactions. With the exception of a few cases of pure dissociation (such as the resolution of gold oxide into metal and oxygen under the influence of light), which have no direct bearing on photographic processes, the photochemical changes with which the photographic chemist has to concern himself may all be considered from the same point of view as those which have been made use of by way of special illustrations. There is no fundamental difference in principle between the action of light on a mixture of ferric chloride and oxalic acid, or mercuric chloride and ammonium oxalate, and its action on a silver haloid mixed with water, silver nitrate, sodium sulphite, gelatine, or any other organic compound capable of being oxidized or halogenized. The only differences are in the relative velocities of chemical change, and in the circumstance that in the case of such metals as iron and mercury the products are definite and known, while in the case of silver the products are indefinite and unknown. The student will thus be led, without a break, from ordinary chemistry to photochemistry, and from the latter to the chemistry of photographic processes. He will now realize that the photographic film is to be looked upon as a system of chemical compounds capable of undergoing atomic rearrangement under the influence of the external energy of light. He will grasp the full meaning of the term "sensitizer," and he will see that the function of the latter is quite as important as that of the silver haloid itself.

From this point the practical study of photographic methods, the preparation of emulsions and films, the uses of collodion and gelatine as vehicles, the action of preservatives, and all the technical details of modern processes, can be taken up or resumed. Then in natural sequence will follow the consideration of the nature of the photographic image and its connection with the colored products resulting from the prolonged action of light on the silver haloids. At this stage, again, caution is necessary, and dogmatic statements must be avoided. The action of light on the sensitive films in use in photography, including all the films employed for producing pictures in the camera, from the iodized silver plate of Daguerre to the gelatino-bromide plate of modern times, gives rise to no visible product of photochemical decomposition. Is it therefore legitimate to conclude that the short exposure necessary to give a developable picture produces any photochemical decomposition at all? It must be pointed out that there is here another gap in the way of direct proof, but that the indirect evidence is all in favor of there being such a chemical change. Of the nature of the material composing the invisible image we know no more than we do of the composition of the colored products of photochemical decomposition, or of the photosalts. They may be identical or not, but that the image is the result of a true chemical change can be made to appear highly probable to the student by a few well chosen demonstrations. Let us consider the evidence as it stands.

The invisible image is either the product of chemical decomposition, or it is not. If it is not, then some other explanation must be invoked. The only other view is that the energy of light is not at first used up in doing chemical work, but that before true chemical decomposition occurs there is an intermediate stage, during which the energy is engaged in loosening the affinity between the atoms of the halogen and the silver. This would be analogous to Bunsen and Roscoe's "photochemical induction." According to this view, we should have to regard the first action of light on the sensitive film as a purely physical action, resulting in the formation of an unstable modification of the silver haloid, more easily reducible than the ordinary modification. It might be thought that such a physical modification would be easily producible by the limited action of light on the pure silver haloid, but as far as my own experiments have gone, this does not appear to be the case. By exposing pure, dry silver bromide films, obtained by the method already described, for sufficient time to produce a well-defined developable image on a photographic plate, no difference in the reducibility of the exposed and unexposed parts could be detected. In fact, the films of the pure haloid are so insensitive that an exposure to bright sunlight of sufficient duration to completely solarize the slowest of modern dry plates showed no difference in reducibility by potassio-ferrous oxalate or alkaline pyrogallol between the exposed and unexposed portions of the surface. The conclusion to be drawn from these experiments is that in this form the silver haloid cannot be converted into a more easily reducible physical modification by any moderate exposure to light—certainly not by an exposure considerably greater than that necessary to impress an image on a gelatino-bromide plate.

At this point the question of molecular aggregation comes into consideration. Is it not possible that in the iodide film of the old collodion process, or in the gelatino-bromide emulsion, the silver haloid is in a different and more highly sensitive state of molecular aggregation? Is there, in fact, a more unstable condition of the haloid than that resulting from the action of the halogen on a silver mirror on glass? In considering this part of the subject, attention may be called to the experiments which the student has already been recommended to make in connection with the modifications of the haloids. His experience in the preparation and ripening of emulsions will also render good service in enabling him to fairly consider the evidence. It is possible that some weight—how much it is not yet possible to decide—may have to be given to the state of aggregation as a factor in determining the extreme sensitiveness of the photographic film. At the same time it must be pointed out that no experimenter has ever yet succeeded in preparing a film of silver haloid in any state of aggregation free from every suspicion of a sensitizer, and capable of receiving an invisible and developable impression in the same time as an ordinary photographic plate.*

We are thus brought face to face with the remarkable fact that a film of pure dry haloid gives no product which is more easily reducible than the original haloid by any reasonable amount of exposure to light. Let the same haloid be diffused in fine particles throughout a sensitizing vehicle such as collodion (with the necessary preservative) or gelatine, and an exposure for a few seconds or a minute fraction of a second gives a product which is far more readily reducible than the unexposed haloid. It may be pointed out that it is extremely difficult to see where the necessity for invoking the physical theory of the photographic image comes in when these facts are fairly weighed.† The facts themselves can be easily

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* It must be recognized that the definite character of molecular compounds passes into the indefinite when we have ½ H_2O, ½ $C_2H_4O_2$, ½CH_4O, etc., in crystalline products.

† The analogy between a photosalt and a saturated solution was indicated in a lecture delivered last year at the Royal Institution ("Proc. Roy. Inst.," vol. xiii, p. 143). The idea of a "solid solution" may appear somewhat strained, and I am glad, therefore, of the present opportunity of calling attention to a similar idea which has occurred to others in connection with a totally different branch of chemistry, viz., the affinity of coloring matters for fabrics. This notion has been expressed by Dr. E. Knecht ("Journ. Soc. Dyers and Colorists," 1889, p. 77), and recently it has been extended with considerable force to the theory of dyeing by my friend Dr. Otto N. Witt ("Faerber Zeitung," 1890–91, Part 1.

‡ The above experiment is a modification of one described by Robert Hunt ("Researches on Light," 2nd ed., p. 78). This method has recently been applied by R. Hitchcock ("Amer. Chem. Jour.," xi., p. 474) for determining quantitatively the loss of weight in films of silver chloride exposed to light in an atmosphere of hydrogen. The author considers that his experiments prove that oxygen does not enter into the composition of the darkened product, *i. e.*, that they disprove the oxychloride theory. But since water vapor was present, and was indeed found to be indispensable for the photodecomposition, this inference cannot be allowed much weight. Moreover, since hydrogen is known to reduce the chloride to silver under the conditions of the experiment, the darkened product may have a different composition to that formed in air: it may consist of reduced silver, mixed with unaltered chloride. (See also C. H. Bothamley in "Brit. Jour. of Photog.," April 4, 1890.) Hitchcock's films were prepared by allowing finely divided silver chloride, obtained by precipitation, to subside on glass. (Herschel and Hunt's method.) After being washed and dried under a desiccator, the films were but slightly darkened in dry air, even after an hour's exposure to bright sunlight. The introduction of water rapidly increased the rate of darkening, thus furnishing another illustration of the very familiar fact that water acts as a sensitizer. This point was illustrated during the lecture by two experiments, conducted simultaneously. Stripe of paper, coated with the chloride and bromide respectively, were partly screened by black paper, the exposed portions being partly wetted with distilled water. The chloride paper was allowed to remain exposed to the electric light till visibly colored; the bromide paper was withdrawn after a few seconds and developed with weak ferrous oxalate developer. In both strips the portion wetted with water was distinctly darker than the exposed dry part of the coated paper.

* Ostwald unhesitatingly affirms, both with respect to the wet collodion and gelatino-bromide emulsion processes, that traces of metallic silver are liberated by the action of light. ("Grundriss der allgemeinen Chemie," pp. 362–363.)

† According to a recent research by Dr. A. Richardson ("Journ. Chem. Soc.," vol. 59, p. 539), the chloride darkened under water does not contain oxygen. I learn, however, from Mr. H. B. Baker, of Dulwich College, that he has come to an opposite conclusion. His experiments are not yet completed, but he considers that the evidence in favor of the view that the darkened chloride contains oxygen is quite conclusive. He has measured the oxygen absorbed and the oxygen evolved by the action of chlorine on the darkened product.

* According to Stas the third (granular) modification of AgBr (both the white and yellow forms) are extremely sensitive to light. He states that on boiling (with water?) in a glass flask they become darkened in two or three seconds by the blue flame of a Bunsen burner. It is not clear from the description whether he attributes the darkening to the light of the burner alone, but the conditions are obviously very different from those which exist in a photographic film. It would be of interest and importance to reinvestigate this modification of AgBr from the photographic point of view. With reference to the production of an invisible image on a film of AgI on glass, opinions are divided (compare Abney, "Treatise on Photog.," 5th ed., p. 25, and Eder, "Handbuch," Part II., pp. 11 and 20). The authority for the statement that such an image can be produced is Carey Lea. In order to submit the question to the test of experiment I have made, with the co-operation of Mr. T. H. Norris, some further experiments with iodized silver mirrors on glass. The results with alkaline developers are the same as those with the brominated mirrors; there is no difference in reducibility between the exposed and the unexposed portions of the film. With an acid developer, however, a developable image is produced. A plate was half covered by a black screen and the uncovered portion exposed for five minutes to the light of the electric arc. The developer was the ordinary pyrogallol solution withacetic acid as a restrainer and a few drops of $AgNO_3$ solution. The silver deposit formed on the exposed portion long before the unexposed half was attacked. This confirms Carey Lea's results, and at the same time opens up a very wide question, viz., whether photochemical decomposition is necessary for development by accretion as distinguished from development by reduction. It may be that photophysical change is competent to give an image capable of accretional development. It is known that the silver haloid when crystalline is susceptible of photophysical change (Schultz-Sellack, Pogg. Ann., vol. 143, p. 430).

† In his inaugural address to the Photographic Section of the Liverpool Physical Society (Jan. 18, 1891, "Photography;" Feb. 19 and 20, 1891), Dr. F. Hurter states that it has always appeared impossible to him "to reconcile the short exposures necessary for the production of photographic images with any theory which demanded the absolute separation of the halogen, or part of it, from the silver." He bases his objections to this (chemical) theory on quantitative experiments, which go to prove that the energy supplied by the initial source of light is totally inadequate to account for the decomposition of the haloid, or the quantity of silver produced on the film by subsequent development. I

demonstrated without any appeal to a photographic plate. It is only necessary to take one of the brominated silver mirrors and streak it with a dilute solution of gelatine, allowing the solution to remain for ten or fifteen minutes in contact with the film. The gelatine strips can, if necessary, be kept moist by adding water from time to time The plate is then exposed to strong light for a few seconds, washed with warm water to remove the excess of gelatine, and then developed with a weak ferrous oxalate solution containing plenty of potassium bromide. If the experiment has been properly made, the stripe under the gelatine develops before the remainder of the film is attacked.

From this and many analogous experiments which might be made or quoted,* it will be made clear to the student that the function of the sensitizing vehicle is of a very high order of importance. It will be seen also that the particular vehicle now in vogue, gelatine, is a particularly good sensitizer, and it is legitimate to connect its sensitizing action with its well known power of taking up bromine. It may be asked whether it is more probable that mere contact with a solution of gelatine should so alter the physical condition of the haloid (as in the last experiment) as to convert it from a comparatively insensitive to a highly sensitive physical modification, or whether it is more probable that the gelatine should act in the same way as the reducing agents used as sensitizers in the former experiment with the coated papers. It may, I think, be fairly taught that the balance of probability is in favor of the purely chemical action of the gelatine. In accordance with this view is the fact that no collodion emulsion, however the haloid may be modified in physical condition by "ripening," can be made as rapid as a modern dry plate. On the other hand, in favor of the view that some weight must be given to the state of aggregation, it may be pointed out that the silver bromide on glass, although considerably increased in sensitiveness by contact with a gelatine solution, is still much less sensitive than the emulsion.

If, therefore, it is regarded as improbable that mere contact with a gelatine solution can alter the physical condition of the haloid, it may be asked what happens during the ripening of an emulsion. The student will have learnt that when silver bromide is first precipitated in gelatine, the emulsion is comparatively insensitive. It is only by long contact with the gelatine solution at the ordinary temperature, or by the action of heat for a shorter period, that the emulsion acquires its maximum sensitiveness. It is believed by the majority of photographic chemists that the change which occurs during this process is a purely physical one—that there is a growth in size of the particles accompanied by corresponding changes in optical properties.† As already stated, it is possible that some such physical change of condition may occur, and that the increase of sensitiveness may be partly attributable thereto. The condition of the bromide particles in an emulsion is, from the beginning, very different from the condition of the bromide on a film prepared by brominating a silver mirror on glass. Nevertheless, I do not believe that we are at present justified in teaching dogmatically that the whole increase in sensitiveness is due to physical modification only. I must confess that, from experiments which I have been making, and which I hope at some future time to continue, I am gradually coming round to the view that more and more weight must be given to the probability of combination between the silver haloid and the gelatine, and less weight to the state of molecular aggregation, than has hitherto been conceded. If analogy is wanted in support of this view, it is only necessary to remind you of the existence of the "gelatino-nitrate" of silver prepared in a former experiment. If gelatine can combine with silver nitrate to form a compound capable of photo-chemical decomposition, it is not unreasonable to suppose that a similar kind of compound might be formed from a silver haloid and gelatine, or some constituent of the gelatine, under the conditions essential for ripening an emulsion. It is desirable that the photographic chemist should be prepared for the proof, which may be at any time forthcoming, that the marvelous sensitiveness of the modern dry plate is not altogether due to the particular state of aggregation of the silver haloid, but that the substance which is so sensitive to light is an organic silver haloid compound belonging to that indefinite "molecular" group so frequently met with in this branch of chemistry.

From this stage onward, the practical study of photographic processes may be carried on hand in hand with the demonstration of the chemical principles concerned. The photographic image will be regarded as being most probably composed of a product of true photochemical decomposition. This product may, or may not, be identical with the "photo-salts," but it is not improbable that its composition may vary according to the nature of the vehicle with which the silver haloid is associated. The sensitive film which is now in general use will be regarded as a "gelatino-bromide," in the same sense that the term "gelatino-nitrate" has been employed. The photographic image will be looked upon as a design on the surface of the gelatino-bromide, composed of a chemical product more easily reducible than the gelatino-bromide, and invisible simply because of the extreme tenuity of the deposit. When a reducing agent is applied, the material composing the invisible image is alone reduced to metallic silver,‡ and the picture is said to be "developed." The subject of development may now be dealt with, and the chemical principles of the process demonstrated. It is necessary to commence by pointing out that a photographic developer may act in two distinct ways. In development by vapor, as in the daguerreotype, and in the so-called acid developers, there is an accumulation of finely divided metal (resulting from condensation in the case of mercury vapor, and from chemical reduction in the case of acid developers) on the material of the invisible image only. If, for example, silver nitrate is reduced by ferrous sulphate or pyrogallol, the pulverulent deposit of metal accumulates by preference on the product of photochemical action, and continues to be deposited thereon as long as there is silver being deposited from the developing solution. Where the silver deposit has once formed, there it continues to grow by accretion, and the developed picture is built up of metallic silver. The action is, doubtless, of an electrolytic character, the material of the invisible image and the unaltered haloid forming the two elements of a galvanic couple, and the developing solution playing the part of the electrolyte. To illustrate the mode of action of developers of this class, it is only necessary to use one of the silver on paper designs produced as in the first lecture. An extremely faint design in reduced silver, on being immersed in a solution depositing the metal by reduction, becomes darker and darker by the process of accretion. In order to broaden the student's notions, it must be pointed out, and illustrated experimentally, that this process is not peculiar to silver. A design in any freely divided metal, such as mercury, gold, or platinum, produced by reduction (chemical or photochemical) on a paper surface can be "developed" in the same metal, by immersing it in the solution from which the metal is being deposited by chemical reduction.

The other kind of development effected by such reagents as ferrous oxalate, alkaline pyrogallol, eikonogen, and hydroquinone, must be regarded as also due to reduction; but, in these cases, it is the material composing the invisible image which is directly reduced. This constitutes the so-called alkaline development. It must be taught, in connection with this subject, that the silver deposit which results from the reduction of the invisible image is not the exact equivalent of the quantity of material composing that image, but that the reduction commenced on the portions exposed to light extends downward through the film as long as the developer is acting. In fact, it must be made clear that the silver deposit *grows* by continued reduction, the action in this case also being most probably electrolytic, the elements being the first film of reduced silver, the unchanged haloid with which it is in contact, and the developing solution as the conducting medium.

The final result of both kinds of development is the production of a silver picture, composed of far more silver than can be accounted for by the actual quantity of the material composing the invisible image. The two kinds of development may be classified as "accretional" and "reductional" (chemical and physical, according to the Continental photographers). The broad principles of the process having been elucidated, the student may proceed to the study of the individual developers, their mode of preparation, and the probable chemical changes which they undergo when acting upon an exposed plate. In dealing with the latter point, it is not essential that the actual composition of the material composing the invisible image should be known; it is only necessary to regard the action as occurring between free halogen and the reducing agent in the presence of water. In the case of such a developer as ferrous oxalate the chemical change is sufficiently obvious, but the action of halogens and water upon organic reducers is far less definite, and it will be safer to abandon all attempts to represent the changes by equations in the present state of knowledge. It may be less satisfactory, but it is a more truly scientific attitude to confess imperfect knowledge than to invent nicely balanced equations which may be quite remote from the truth.

Having mastered the principles of development, it is important that the student should have his attention directed to certain phenomena which connect this subject with the initial action of light on the photographic film. He will have learnt from the previous demonstrations that the photographic image with which he is practically familiar is most probably a product of photochemical decomposition. He will thus be prepared for the proof that chemical reducing agents may act in the same way as light; that is to say, that by employing a very slow reducer and allowing it to act on the silver bromide for a short time, the reduction is carried to the same stage as that which results from the initial action of light. The process of reduction can be arrested at the invisible stage—at a stage intermediate between the haloid and the free metal. The product thus formed, whatever its composition may be, is more easily reducible than the original haloid, and can therefore be "developed" by ferrous oxalate, etc., in just the same way as the invisible image. The simplest way of showing this is to stripe a sheet of paper coated with the haloid with an alkaline solution of glucose, allow the latter to act for a few minutes, wash thoroughly, and then develop with weak ferrous oxalate containing plenty of soluble bromide. It may be pointed out that such a result as this, for the experimental demonstration of which we are indebted to Carey Lea, is opposed to the physical theory of the photographic image, since it is difficult to see how the mere contact of a silver haloid with a feeble reducing agent can modify the physical stability of the haloid so as to transform it into a chemically unstable modification.

Another fact bearing on the present subject, which must not be overlooked, is that mechanical force of the nature of a shearing stress also produces a developable impression on a silver haloid film. So far as my experiments have gone, this result cannot be produced except in the presence of a sensitizer; any of the ordinary photographic films will show it, but I have thus far been unsuccessful with the halogenized mirrors on glass. Although negative evidence does not count for much, it appears thus far that the effect is only producible under the same conditions that an invisible image is produced by light. If this be so, then we have an additional argument in favor of the chemical theory of the photographic image, for the researches of Prof. Spring of Liege have shown that a mixture of compounds can be made to undergo chemical interaction by mechanical pressure alone. The silver haloid and its associated or combined sensitizer provides such a mixture or compound.

In connection with the necessarily related subjects of exposure and development, the phenomenon of reversal must be dealt with. I regret exceedingly that time is pressing me toward a conclusion, and that I can do no more than hint at the mode of treatment of this important subject. I have already expressed the view* that this phenomenon is best regarded as reversed chemical action between the halogenized sensitizer and the material of the invisible image. Since that view was put forward three years ago, no new facts have been adduced which are in opposition to it, and I am therefore bold enough to think that it is at any rate worthy of being taken into consideration by the teacher of photographic chemistry. In the broadest possible terms all that we have to consider is that the "photosalt" in contact with a sensitizer containing more than a certain quantity of halogenizing or oxidizing material has the tables turned upon it, to speak metaphorically, and then acts as a sensitizer toward the film which at first acted as a sensitizer toward it. The principle can be demonstrated by utilizing a very old experiment. It is known that potassium iodide is capable of undergoing photochemical oxidation in the presence of moisture and air; iodine and potassium hydroxide are formed, and of course interact in the absence of some other iodine absorbent. A photosalt is an iodine absorbent, and therefore if a sheet of paper be coated with a silver haloid, and then exposed to light till it darkens, we have a surface capable of sensitizing a solution of potassium iodide, so that the latter undergoes photochemical oxidation with extreme rapidity, the liberated iodine being absorbed by the photosalt, which thereby becomes bleached, *i. e.*, converted into the ordinary haloid.

Having brought the student up to this stage of knowledge, we must leave him in possession of a silver picture produced by development, and the chemistry of the subsequent operations of fixing, clearing, intensifying or reducing, printing, toning, and so forth, will be comparatively simple, after the course through which he is supposed to have been conducted. With regard to these subsequent operations, all that has to be borne in mind is that, after fixing and washing, the image is composed of a graduated deposit of metallic silver, and that all the changes that are wrought upon it by intensifiers or reducers are simply the result of ordinary chemical transformations. Thus the principle of intensification may be demonstrated in the usual way, viz., by producing a design in silver on paper, as in the first lecture, then bleaching it by immersion in a solution of mercuric chloride, and, after washing, converting the mercurous chloride formed into the dark dimercurous ammonium chloride. The final result is a more opaque image—the latter has become intensified.

I have, perforce, been obliged to keep rigidly to my programme in this course of lectures; there has been no time for straying into by-paths, and I have confined myself strictly to the chemical aspect of the subject. I said, at starting, that it has also its physical side, and the special action of the spectrum colors on the different photo-sensitive compounds, the electrical phenomena accompanying development, the action of special sensitizers in connection with orthochromatic photography, the subject of heliochromy, etc., must be included in every complete course of instruction in photographic technology. It has been my object to indicate the general lines on which this branch of technical training should be conducted; the teacher will no doubt discount the personal element from these lectures as far as he may think desirable, and after he has done this, if he will conduct the student along the broad track toward which I have acted the part of a finger post, we may call into existence a race of technologists who will raise the subject of photography to that high position as a science which it has already taken as an art.

VOLUMETRIC ANALYSIS.

ONE of the more important additions to the minor examination, which will for the first time be taken at the October examination, is volumetric analysis. Hitherto this subject has been confined to major candidates, and we may safely say that all others have left it severely alone. We know from the prospectuses of the schools that the subject will receive immediate attention from teachers, but a large number of students, who may not attend a school for some time, will be anxious to have volumetric analysis explained on a less ambitious scale than is presented in the standard text books on the subject. For such this article, which has been given as a lecture to students, is intended.

Given a piece of lunar caustic, by qualitative analysis we find that it is composed of nitrates of potash and silver, and, to ascertain the quantity of silver, we may take a gramme of the caustic, dissolve it in water, add excess of common salt, collect the precipitated silver chloride, wash, dry, and weigh it, and may find that it corresponds to 95 per cent. of silver nitrate. This is a *gravimetric process*, or measurement by weight. As we know from the law of combining proportions that certain proportions only of common salt and silver nitrate are involved in the decomposition which takes place, and when we express that decomposition as

$$AgNO_3 + NaCl = AgCl + NaNO_3,$$

we not only represent the nature of the decomposition, but the weight of the substances therein involved. Knowing, therefore, that $AgNO_3 = 170$, and $NaCl = 58{\cdot}5$, it follows that, if we have a solution of common salt the strength of which is known, and add that solution to the silver solution as long only as silver chloride

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does not appear to me, however, that these experiments or calculations in any way affect the chemical theory of the photographic image. The actual amount of photochemical decomposition, as measured by the quantity of silver produced on reduction, may be, as the author states, connected with the initial source of energy by a logarithmic law. But this does not prove that no separation of halogen takes place; the energy is not to be regarded as acting upon AgBr alone, but upon a most intimate mixture or possibly even upon a compound of AgBr and gelatine. The latter substance is well known to combine with bromine to a very considerable extent (20·5—23·9 p. c.; see Weyl in Chem. Centralbl. 1878, p. 198, and Knop, *ibid.*, 1879). The action of light on the photographic film is rather comparable with the action of heat on an explosive mixture or compound; the total energy evolved on the explosion of gunpowder is not dependent on the amount of energy supplied by the spark which determines the explosion.

* See Sec. III. of Chap. X. of Eder's "Ausfuhrl. Handb.," Part III.

† For further particulars, see "Chemistry of Photography," pp. 120, 122.

‡ It is well known that a reducing agent of sufficient strength to reduce silver bromide directly, such as the ordinary ferrous oxalate developer, may be applied with a gelatino-bromide dry plate. It is generally taught that the haloid is protected in such an emulsion by virtue of the particles being embedded in the gelatine. I am disposed to believe, however, that the protection is not merely physical, but that the weak chemical combination between the haloid and the gelatine (or one of its constituents) results in the formation of a compound less reducible than the haloid itself. I may point out, incidentally, that the change in size of the particles, and the modification in optical properties undergone by the emulsion during the process of ripening, as well as the increase in sensitiveness, are all in accordance with the chemical theory of the gelatino-bromide film.

* "Chemistry of Photography," pp. 230-236.

is precipitated, we can calculate from the amount of common salt used the amount of silver nitrate in the weight of caustic employed, thus doing away with the washing, drying, and weighing of the precipitate. This is *volumetric* analysis.

The method was discovered as long ago as 1806 by Descroizelles, a French chemist, and rediscovered in 1817 by Mr. Charles Tennant, of Glasgow. But Dr. Andrew Ure was the first, and that in 1817 also, to use volumetric methods, based (as he expressed it) "on the lights recently shed on chemical proportions by Dr. Dalton's atomic theory, and thus made the standard solution represent not arbitrary (as in Descroizelle's method) but absolute measures." It was not until 1844, however, that Dr. Ure established his claim, and by that time volumetric analysis had come into general use, particularly on the Continent. Gay Lussac had experimented and devised at least two processes, which are still in use—namely, estimation of free chlorine with arsenious acid, and silver with common salt, the latter method giving origin to the word *titration*, as applied to the volumetric process, being derived from the French word *titre*, standard (of gold or silver). Liebig had devised that beautiful process, now pharmacopœial, for the estimation of hydrocyanic acid; Bunsen, Schwartz, Fresenius, and Will gave the art great impetus by their careful researches. Dr. Mohr, of Coblentz, revised all that had been done by previous investigators, devised new processes and the burette which is now so much used, thus placing the art in a state of efficiency which has called for little revision. Helpers were not wanting in our own country, but we need only mention the name of Francis Sutton, whose treatise on volumetric analysis has no peer in our language.

PRINCIPLES.

Based primarily on the incontrovertible law of combining proportions, the practice of volumetric analysis involves several recognized principles, which we may generalize as:

1. A constant and known reaction between the reagent and the substance titrated, the end of the reaction being capable of easy and quick determination.
2. Standard solutions of reagents whose strength is related to the chemical weight unit—hydrogen.
3. Employment of apparatus graduated on a decimal system.

Though third in order, the graduated apparatus is not the least important requirement. Taking the Pharmacopœia as our guide, we find there given option of two systems of weights and measures for graduation—namely, the grain and gramme systems. The latter is generally used in scientific work, but the grain system gives exactly the same results. The apparatus ordered consists, in the case of the metric system, of a liter flask, a graduated liter jar, and 100 c. c. burette graduated to 100 divisions. A more suitable burette is one of 50 c. c. graduated to $\frac{1}{10}$ c. c. Mohr's burette, with a perforated stopper, is the best form. Annexed is an illustration of a good set of apparatus, graduated on the grain-measure system, which is offered by Messrs. Poths & Co., Creechurch Lane, E. C. The set comprises all the graduated apparatus required for the preparation of standard solutions and for titration, with a burette stand, the whole being inclosed in a box.

The apparatus can be had in English or metric graduations. As some workers find it difficult to read off the amount of solution used, it is of advantage to put into the burette an Erdmann's float. This is scored round the circumference. The level of the line is brought to 0 on the burette before an estimation is commenced, and the graduation it is at at the end shows how much solution has been used. A float costs 6d. A few flasks, beakers, and 5 c. c. and 10 c. c. pipettes, if metric measure is used, are also required. A good set of dispensing scales can be used for weighing if a balance is not at hand.

STANDARD SOLUTIONS.

It is very important that the operator should thoroughly understand what is meant by standard solutions. It has already been said that their strength is related to the chemical weight unit, hydrogen. This is attained in two ways:

1. The solution may contain an arbitrary quantity of the reagent, its strength being ascertained—technically speaking, *standardized*—before use. This plan is adopted in the case of substances (such as potas. permang.) which are liable to deteriorate in aqueous solution.

2. The solution may contain in a liter the hydrogen equivalent of the reagent weighed in grammes (1 grain in 1,000 grain measures), or decimal parts of such weights, or any known weight. This is the plan adopted in the Pharmacopœia.

The following examples will illustrate the meaning of the system:

a. One liter vol. soda solution contains 40 grms. of caustic soda (NaHO = 40), or 40 gr. in 1,000 gr. measures. This solution contains a full hydrogen equivalent (sodium being a monad), hence it is called normal; written, $\frac{n}{1}$.

b. One liter vol iodine solution contains 12·7 grms. of iodine (I = 127), or 12·7 gr. in 1,000 gr. measures. This solution contains only one-tenth of the hydrogen equivalent (iodine being a monad), hence it is called decinormal; written, $\frac{n}{10}$.

The reactions which take place will be most conveniently studied under the respective solutions; meanwhile we may group them under several general phenomena or bases of action, but it is not always possible to draw a hard-and-fast line between these.

	Solution.	Basis of Action.
Decinormal Normal	NaHO $H_2C_2O_4$ 2 H_2O	Saturation.
	$AgNO_3$	Precipitation.
	$K_2Cr_2O_7$ ($\frac{n}{10}$ of Fe''_2)	Oxidation.
	I	Oxidation.
	$Na_2S_2O_3$, 5 H_2O	Reduction.

In practice the determination of the completion of these phenomena is essential to accuracy. In some cases the completion is self-indicative, as in the use of iodine solution, when the first permanent tinge of iodine color shows that oxidation is complete. Other phenomena, however, do not give such indication, and in most of these we add substances which are acted on by the reagent or substance under examination, so that the *final reaction*, or "end point," may also be indicated by a change or disappearance of color. Such substances are termed *indicators*, and are either placed in the titration vessel (internal indicators) or on a white porcelain surface (external indicators).

SATURATION

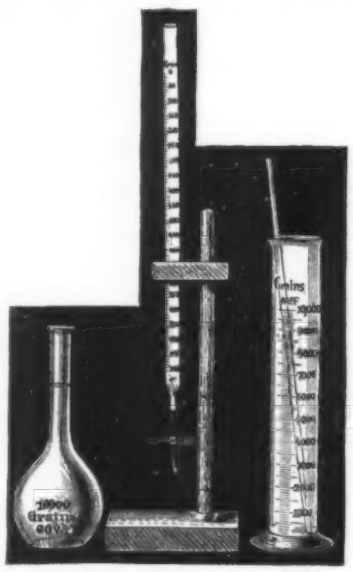
in volumetric analysis is synonymous with *neutralization*, for the saturation of an acid with an alkali, or *vice versa*, gives neutrality. There is no rule without its exceptions, however, and we find that some of our saturation processes are not neutral at any stage. Where neutrality is effected, litmus tincture is generally used as an indicator. We have others, such as cochineal, methyl orange, and phenolphthalein; but all beginners should use litmus, its changes being most familiar. Phenolphthalein may be used for the acids indicated on page 496 of the B.P.

In making volumetric solution of soda the graduated measure is required. Starting with caustic soda, dissolve an ounce of the white sticks in about 9,500 gr. measures of distilled water (or 42 grms. in a liter), and after the solution is cold, estimate its strength as the B.P. directs, but divide the 1,000 gr. measures of acid solution into two portions of 500 gr. each, and make two estimations. In the first trial one may go a little over the mark, but this is not so likely in the second. Titrations should as often as possible be made in duplicate, the mean of the two being taken for calculation.

The Pharmacopœia orders this solution for determining the strength of various acids. In each case a certain weighed quantity is ordered, but we may preferably take any quantity and weigh it. Should the percentage by volume be required, then the acid is measured with a pipette. Weight is in all cases preferable to volume, because the latter is affected by temperature, while the former is not.

Calculations are made on the following basis:

One liter of solution [in this and subsequent notes



observe that you may read for "one liter" "1,000 gr. measures," and for "gramme" "grain."] =

(*a*) Molecular weight in grammes of a *monobasic acid—e. g.*, acetic, hydrochloric, and nitric acids.

(*b*) Half-molecular weight in grammes of a *dibasic acid—e. g.*, sulphuric and tartaric acids.

(*c*) Third-molecular weight in grammes of a *tribasic acid—e. g.*, citric acid.

Suppose we make an estimation of aqueous sulphuric acid, and find that 5 c. c. of the acid require 35·5 c. c. of soda solution for neutralization:

Calculation: $H_2SO_4 = 98$; being dibasic, 1 liter = 49; then 1 c. c. = $\frac{49}{1000}$, or 0·049.

0·049 × 35·5 × 20 = 34·79 of H_2SO_4 by weight in 100 vols.

To find percentage when any quantity of the material is taken, let x = quantity taken, v volume of soda solution used, and w the weight of acid which 1 c. c. of soda solution neutralizes, then:

$$x : w \times v :: 100 : \text{percentage.}$$

Since the relation between the soda solution and the acids is so definite, it follows that the student should always know how much of any particular acid a grain measure or 1 c. c. of the soda solution will neutralize. One thousand parts of the solution neutralize the molecular weight in such parts of a monobasic acid, half molecular of dibasic, and so on. Therefore, such notes as the following might be put on the soda bottle or in the note book:

1 grain measure	= 0·040 gr.	$HC_2H_3O_2$
1 " "	= 0·049 "	H_2SO_4
Or 1 c. c.	= 0·040 grm.	$HC_2H_3O_2$
1 "	= 0·049 "	H_2SO_4

It follows that by simply multiplying these factors by the grain measures or c. c. of soda used, the quantity of acid in the portion taken is found. The same arrangement may be used for all the standard solutions.

Volumetric Oxalic Acid Solution.—Oxalic acid ($H_2C_2O_4$ 2 H_2O = 126) being dibasic, only half its molecular weight in grammes is contained in a liter, consequently equal volumes of soda and acid solutions should form a neutral mixture. The chemically pure acid, powdered and pressed in filter paper, may be used for making the solution. Except with lead salts, we use litmus as an indicator in titrating all the substances which come under this solution. The substances react with the acid to form oxalates of the base, water, and, in some cases, carbonic acid, being liberated. Where CO_2 is given off, it is necessary to boil the mixture, so that its effect on the litmus may not impair the results. Borax reacts with the acid to form oxalate of sodium and boric acid; but in this case the freed acid only feebly affects litmus, so that its use is not precluded. As an illustration, we may estimate a sample of ammonia solution, and we may find that the 5 c. c. taken require for neutralization 18 c. c. acid solution.

Calculation.—Ammonia gas (NH_3 = 17) is a monad compound radicle, so that 1 liter of acid solution equals 17 grms. NH_3, 1 c. c. = $\frac{17}{1000}$, or 0·017. Therefore 0·017 × 18 × 20 = 6·12 per cent. of NH_3.

The c. c. equivalent of the acid solution to the various substances estimated therewith may be calculated from the following:

One liter of the acid solution is equivalent to:

(*a*) Molecular weight in grammes of salts, showing *one hydrogen equivalent of alkaline base—e. g.*, ammonia, bicarbonates, borax, caustic potash and soda, and acid tartrate of potash.

(*b*) Half-molecular weight of salts, showing *two H* eq. *of alkaline base—e. g.*, carbonates, lead acetate, oxide of calcium, and normal tartrates.

(*c*) Third-molecular weight of salts, showing *three H* eq. *of alkaline base—e. g.*, normal citrates.

(*d*) Fourth-molecular weight of salts, showing *four H* eq. *of alkaline base—e. g.*, lead subacetate.

Citrates and tartrates are first incinerated, thus being reduced to carbonates, then the titration is proceeded with.

Lead Acetates.—There is a special difficulty with these salts, due to the fact that they react with the oxalic acid to form insoluble lead oxalate and acetic acid; consequently, litmus and the other saturation indicators do not indicate the final reaction. The only indication is cessation of precipitation, but the oxalate subsides very slowly in the cold, and it is so bulky that one is apt to run in too much oxalic acid. Use hot water or the reversed process (*C. & D.*, 1883, page 609).

PRECIPITATION PROCESSES.

In these the final reaction depends on (1) the beginning, or (2) cessation of the precipitate. Volumetric solution of nitrate of silver is the Pharmacopœia representative of the method. The most important application of the solution is in the estimation of acid. hydrocyan. dil., the method being that devised by Liebig. It depends upon the following changes:

1. Conversion of the hydrocyanic acid into cyanide of sodium by means of liquor sodæ.

$$HCy + NaNO = NaCy + H_2O.$$

2. Formation of soluble double cyanide of silver and sodium.

$$2\ NaCy + AgNO_3 = AgNaCy_2 + NaNO_3.$$

3. Decomposition of the double cyanide by additional silver nitrate:

$$AgNaCy_2 + AgNO_3 = 2AgCy + NaNO_3.$$

The commencement of the third stage indicates the final reaction. In estimating 5 c.c. of acid, a drop of phenolphthalein sol. was mixed with it, and soda added, until a strong crimson color was produced. (Should the crimson color disappear during titration, more soda must be added.) Silver solution was run in, and the precipitate redissolved until 9·4 c.c. had been used, thus indicating commencement of third stage.

Calculation.—From the equation of the second stage it is evident that one molecule of $AgNO_3$ equals two of HCN (= 28). The standard solution being decinormal, 1 liter will, therefore, represent 5·6 grammes HCN, so that 1 c.c. = $\frac{5{\cdot}6}{1{,}000}$, or 0·0056. Therefore—

$$0{\cdot}0056 \times 9{\cdot}4 \times 20 = 1{\cdot}052 \text{ per cent.}$$

In estimating alkaline bromides and iodides, the acidulous radicles are precipitated as insoluble silver salts. The final reaction is indicated with chromate of potash, a drop or two of a weak solution being added to the bromide solution. When all the haloid radicle is acted on, blood red chromate of silver begins to form, and the titration is stopped.

OXIDATION METHODS

rank among the most accurate processes of chemical analysis. They depend for their action on the fact that the reagents used are substances which either (1) readily give oxygen to oxidizable substances, or (2) which in presence of such substances split up water, giving oxygen and taking hydrogen to themselves. In the B.P. we have solutions of each kind.

Volumetric solution of bichromate of potash is a solution of the first kind, and is used for determining the percentage of dyad iron in ferrous compounds. The solution is not the most satisfactory for this purpose (the final reaction requiring an external indicator), but it is more stable than any other, and that is a sufficiently strong argument for its adoption. The solution contains 14·75 grammes in a liter—that is, one-twentieth of the molecular weight in grammes. From the following equation,

$$6FeO + K_2Cr_2O_7 = 3Fe_2O_3 + Cr_2O_3 + K_2O,$$

it will be seen that one molecule of the bichromate gives three oxygen atoms to six ferrous atoms, and, as $O_3 = H_6$, the bichromate molecule, represents six hydrogen equivalents. A decinormal solution (based on the hydrogen equivalence) should, therefore, contain $\frac{1}{10}$ of the molecular weight in grammes —4·917. The B.P. solution, however, is decinormal of *three ferrous atoms* $\left(\frac{n}{10} \text{ of } Fe''_3\right)$ On this basis the solutions will oxidize.

$\frac{1}{10}$ the weight in grammes of	$Fe_3As_2O_8$	1 c.c.	=0·0446 gramme.
" " "	$Fe_2P_2O_8$	"	=0·0658 "
" " "	$3FeCO_3$	"	=0·0648 "
" " "	$3Fe_2O_3$, FeO	"	=0·0696 "
" "	or FeO in $3Fe_2O_3$, FeO		=0·0216 "

The compounds (2 grammes of each) should be dissolved in aqueous sulphuric acid (1—5) with the aid of heat, 2 oz. of water being added after solution. The indicator used is *fresh and weak* solution of red prussiate of potash, the matter of 20 dots or so being placed

round the edge of a white plate. As the bichromate solution is poured into the beaker, the contents should be well stirred with a glass rod (tipped with rubber); occasionally the end of the rod is brought into contact with one of the dots on the plate; as long as there is ferrous compound unoxidized, a deep blue color will be struck on contact. When this ceases, the titration is complete.

Volumetric solution of iodine is a solution of the second kind of oxidizers. The solution being decinormal contains 12·7 grammes of iodine, with 18 grammes of iodide of potassium as a solvent, in a liter. It is used for estimating arsenious and sulphurous acids, both of which are in the process raised to the "ic" state.

Arsenious acid and its solutions are boiled with a little bicarbonate of soda. During titration the following change takes place:

$$As_2O_3 + 2I_2 + 2H_2O = As_2O_5 + 4HI.$$

The hydriodic acid decomposes so quickly that it is necessary to have an alkali present, so that it may be saturated on formation. A bicarbonate is in the circumstances more suitable than a hydrate, because the latter would tend to use up iodine, thus impairing the reaction. It will be seen from the equation that four atoms of iodine give two of oxygen to a molecule of arsenious acid, so that 1 liter of the decinormal solution is equal to $\frac{1}{40}$ of the molecular weight of As_2O_3 (198) in grammes. 1 c.c. $= \frac{4{\cdot}95}{1000}$, or 0·00495 gramme.

Sulphurous acid reacts with iodine in the following manner:

$$H_2SO_3 + I_2 + H_2O = H_2SO_4 + 2HI.$$

In this case alkali is inadmissible. One liter of the iodine solution will raise to sulphuric acid $\frac{1}{20}$ of the molecular weight in grammes of $H_2SO_3 = 82$, or of $SO_2 = 64$.

1 c.c., therefore, equals $\frac{4{\cdot}1}{1,000}$, or 0·0041, H_2SO_3, and $\frac{3{\cdot}2}{1,000}$, or 0·0032, SO_2.

In the titration of these acids a few drops of starch mucilage are added, so that the first excess drop of iodine solution imparts a deep purple color to the mixture, at which point titration is complete.

REDUCTION PROCESSES

are those in which the reagent used is a readily oxidizable substance, so that this class is merely a reversing of oxidation processes. The solution employed (vol. sol. of hyposulphite of soda) reacts with iodine in the following manner:

$$2Na_2S_2O_3\,5H_2O + I_2 = Na_2S_4O_6 + 2NaI + 10H_2O.$$

Here the iodine, instead of giving oxygen, takes two atoms of sodium from two molecules of the hyposulphite, leaving one molecule of tetrathionate of sodium, the acidulous radicle of which is a higher sulphur oxide than that of the hyposulphite (thiosulphuric acid).

The preparation of the solution is explicitly described in the Pharmacopœia. It is used for titrating iodine, either as such or for the estimation of free or available chlorine, which is allowed to act on potassium iodide, liberating iodine, thus: $2KI + Cl_2 = 2KCl + I_2$. From this it is evident that a liter of the solution will decolorize $\frac{1}{2}$ of the molecular weight of iodine in grammes, whether it existed primarily or has been liberated by chlorine; and since one atom of chlorine = 35·5 will liberate one of iodine = 127, it follows that 1 liter of hypo. solution = 3·55 of Cl.

Solutions containing free chlorine have iodide of potassium added to them, but when it is combined, hydrochloric or sulphuric acid is also added. In illustration, we put 5 c.c. of liq. calcis chloratæ into a flask with a few grammes of potassium iodide and excess of hydrochloric acid. Hypo. solution was then added, and, as the iodine color began to fade, a few drops of starch mucilage. When 40 c.c. of standard had been used, the blue color faded.

Calculation.—1 c.c. hypo. solution $= \frac{3{\cdot}55}{1,000}$, or 0·00355, Cl. 0·00355 × 40 × 20 = 2·84 per cent. available chlorine.

The composition of chlorinated lime is doubtful, but Odling's formula—$CaOCl_2$—is generally accepted as the most reasonable representation of its chlorinated constituent, existing along with hydrate and oxide of calcium. Treating this compound with an acid in presence of potassium iodide, the following reaction occurs:

$$CaOCl_2 + 2HCl + 2KI = CaCl_2 + 2KCl + H_2O + I_2.$$

But Kingzett has shown that water extracts from chlorinated lime, calcium chloride and hypochlorite. The latter salt will therefore represent the available chlorine in liq. calcis chloratæ, thus:

$$CaCl_2O_2 + 4HCl + 4KI = CaCl_2 + 4KCl + 2H_2O + 2I_2.$$

This reaction may take place in three stages:

(1) Action of hydrochloric acid on calcium hypochlorite:

$$CaCl_2O_2 + 2HCl = CaCl_2 + 2HClO.$$

(2) Action of hydrochloric acid on hypochlorous acid:

$$2HClO + 2HCl = 2H_2O + 2Cl_2.$$

(3) Action of chlorine on potassium iodide:

$$4KI + 2Cl_2 = 4KCl + 2I_2.$$

We thus obtain one-half of the iodine in a direct manner and the other half indirectly, the whole, it would appear, being double that of the first equation; but Odling's formula represents half of that of Gay Lussac's ($CaCl_2, CaCl_2O_2$), from which, it is generally assumed, *all the chlorine content* is liberated by acids, so that the two equations yet agree as to the amount of their available chlorine.

It has been shown (by Messrs. Dunstan and Ransom) that liquor sodæ chloratæ contains hypochlorous acid; therefore, in estimating this solution, the decomposition is represented by stages 2 and 3.

Such are the pharmacopœial volumetric processes, and it may be said of them that they are calculated to give most accurate results. We cannot close without a word of caution to the operatior to use all means in his power to insure accuracy. Distilled water should always be used; apparatus should be thoroughly clean and rinsed out with distilled water before use, and weighing should be carefully done. It is scarcely possible for us in this variable climate to perform all operations at the normal temperature, but it is most imperative that the preparation of standard solutions should be effected at 60° F., and where the solutions are made every care should be used in their preservation; they have no doubt been judiciously selected for their stability, but there are few things which do not deteriorate in aqueous solution when exposed to direct sunlight; the bottles, therefore, should be covered with seidlitz blue paper and be stored in the shade. Nor must the beginner attempt to operate on small quantities of material, for in such cases a small excess one way or the other may mean a large effect on the results. It is a safe plan to stick to the pharmacopœial quantities to begin with. Above all the operator must recollect that volumetric analysis is not a mere mechanical kind of work, but that it involves the fundamental principles of the science of chemistry, and should be treated with due respect.

MIRROR LENS.

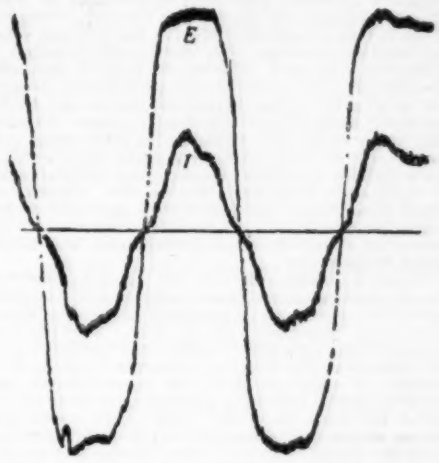
THIS little instrument has been devised especially for the reading of certain English and American journals that are printed in very small type, and the continued reading of which soon fatigues the eyesight. But it may be employed just as well for the reading of manuscript, and in this case it is much easier to use than is the hand lens usually employed.

MIRROR LENS.

It consists of a concave lens designed to give an enlarged image of the characters, and which reflects the latter upon a small plane mirror which lies upon the sheet of paper just above the line that it is desired to be read. As soon as the reading of the line is finished, the apparatus is slid over it, and one immediately perceives the following line in the mirror.—*Les Inventions Nouvelles.*

THE PHOTOGRAPHIC RECORD OF ALTERNATE CURRENT CURVES.

IN a recent number of *La Lumière Electrique* M. Blondel describes some apparatus designed for the determination of the periodic curves representing alternate currents. It consists of an extension of the apparatus originally devised by Joubert, who, it will be remembered, used a contact maker, revolving with the alternate current dynamo, to make connection with a brush once during a revolution, and thus to charge an electrometer to the voltage generated in the dynamo at the corresponding part of the period. By adjusting the position of the brush the voltage could be measured at all parts of the period and the complete curve obtained. After an exhaustive comparison of the effects obtained with galvanometers and electrometers, M. Blondel finds the former preferable, and uses a D'Arsonval galvanometer in series with a condenser instead of the static instrument. It is necessary in this case to use two brushes, one for charging the condenser and the second for discharge through the galvanometer. The two brushes are fixed to an arm movable about the same axis as the revolving contact maker, and this arm is turned at a regular rate by clockwork. The scale on which the galvanometer spot is focused consists of sensitized paper, and is moved vertically by clockwork. The photographic record obtained is, therefore, an accurate trace of the alternate current curve. The curves obtained are potential curves, or current curves, according as the condenser is connected with two points of the circuit whose voltage is required, or to the terminals of a standard resistance in series with the main current. In all the cases described by M. Blondel the apparatus was duplicated. Two galvanometers were used, one for current and the other for potential. The spots of light were, however, focused on the same scale with a common zero, the light being obtained from a powerful arc lamp, and reflected on to the instruments by mirrors suitably placed. The double curve thus obtained is such that corresponding ordinates represent the simultaneous values of the current and electromotive force. The figure given shows the curves



obtained with an arc lamp worked with the alternate currents produced by a Meritens magneto machine. The curve I is the current curve, while curve E represents the electromotive force.

When the apparatus is once set up it is possible in a comparatively short time to make a complete study of an alternator under all circumstances of use. A complete alternate current curve can be obtained in two or three minutes.—*The Electrician.*

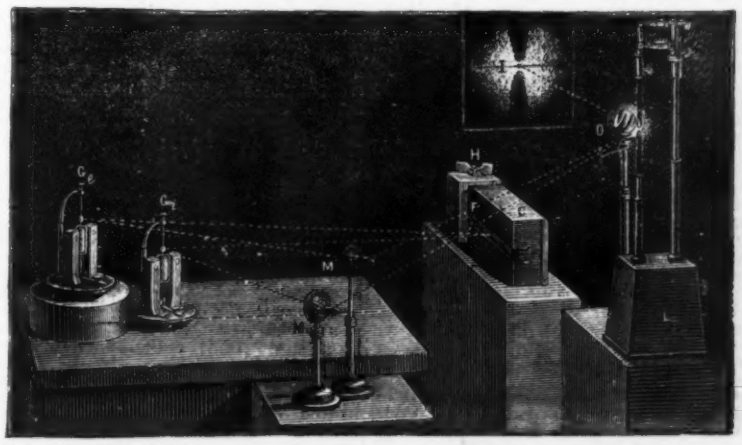


FIG. 1.—I_1 are lamp; O, lens projecting image, I, on to screen; M M, mirrors reflecting beam to galvanometer mirrors, *Ge Gi*; F F', photographic registering slip; H, clockwork for moving the slip.

VAUDOUX BURIAL CUSTOMS.

By EUGENE MURRAY AARON, Ph.D.

FIND him where we may, the African descendant of the least enlightened sort retains a strong flavoring of fetish worship in his composition. It is doubtful if, even under the most civilizing advantages at his command in this country, he has to any noteworthy extent yet been able to eliminate an almost unconquerable inclination to mix with his newly acquired Christianity the old superstitions and not a few of the customs of obeah worship. For this he is scarcely blamable, if any degree of reproach whatever can be attached to such tenacity in holding fast the teachings of long centuries. The German and Scandinavian reach our shores from lands long Christianized, yet they come many of them laden with the beliefs and habit-making superstitions of the pre-Christian days of Thor and Woden. So with our Irish population, and those from Spain and Italy; a Catholicism that has here and there a spice of ghostly lore or act of witchery in it is far from unknown. What wonder, then, that the negro and his derivatives of lighter color are found, by the most conversant with their thoughts and beliefs, to be still under the influence of a strange admixture of the propitiation of evil and visible thank offerings to the giver of good? Can any of his white brothers, as a race, prove entire freedom from kindred taints? Is not the difference simply one of kind and degree?

To one who has lived among the blacks of those West Indian islands where they are the predominating and controlling element—Haiti, Jamaica, Martinique, and others, for example—this feature of their life soon becomes the most interesting branch of ethnological study, if his attention turns at all in that direction. Though these are Christian lands, and in nearly all the church life is an important factor, still the old forms and ceremonies of witchcraft, obeah, vaudoux—much the same under any title—are perhaps even more important in shaping the lives and controlling the actions of a race that so readily lend themselves to any impressive ceremony or teaching, the meaning or intent of which is quite beyond their comprehension. The saying that "the people love

dearly to be humbugged" was no truer from the lips of a Barnum than it might be from those of an obiman speaking of his followers. The "nganga nkisi," or doctor of charms, on the Congo, wins his way to popular favor and awe by the possession of a fetish horn which answers his dupe, as he questions it of the future or asks its advice for the present, by a faint wheezy whistling, though held at arm's length by its owner. Glave tells us that the simple device of a perforated bean, hid in the nostril of the Obiman, is all that is necessary to uphold the reputation of this oracle. Yet the possessor of the secret comes to be a man dreaded of kings, propitiated by warriors, and blindly obeyed by the people. In Catholic Haiti or Protestant Jamaica just such exhibitions of blind faith can be met every day by one who will take the trouble to become *en rapport* with the negroes, when away from close contact with the civilizing action of the cities and villages. The white man is naturally mistrusted by all negro believers in witchcraft, because he it is who has placed upon the statute books the laws which declare their practices criminal. Even in Haiti, under black rule alone, where a timorous government of a day has abolished those laws which a more enlightened rule had enacted, the people recognize that such laws were due to the pressure of opinion from the few resident whites, and not because a negro president or his congress recognized in the vaudoux an enemy to good government, base as are some of its practices.

It is only a question of time and of tact, however, when the patient Anglo-Saxon student of folk-lore and superstitions may become possessed of the confidence of the Obeah worshipers around him. Rare patience and a judicious blending of faith and shillings may even in time open to him the charms and the esoteric mysteries of some priest of Ob whose love of gain leads him to give ear to the professions of faith on the part of his white inquirer. The bird's claws and feathers, fish bones, teeth, and bits of horn, the pieces of colored chalk, charmed hair, perforated stones, pungent herbs, and oddly twisted roots, that are tried media of great power on the Congo and along the whole West African coast, are to-day just as potent in the eyes of the untaught West Indian black. The latter may exhibit a greater degree of skepticism at times; he may require a somewhat higher standard of magic and of ceremonial for his befoolment, but the Obiman to whom he repairs for earthly aid or ghostly comfort seldom fails to produce an effect suited to his particular case.

The thwarting of an enemy, real or imaginary; the procurement of good fortune, whether it be in agriculture, trade, or affairs of the heart, the foretelling of the future, both earthly and heavenly (though for obvious reasons the Obiman much prefers to tell of the latter), and the assuring to the dead a safe entry into a happier state, are among the most common duties to which this priest of witchcraft is called, as they are known to be those of the professors of occult powers elsewhere. But it is in the latter services that the West Indian Obiman, as well as his "nganga" brother of the Congo, or the witch doctor of our Southern States, is most implicitly trusted. Here the field is his, and his alone. In those ceremonies and observances by which he is expected to procure good or produce evil effects, as the case may be, the proofs of which are to be observed by his disciples, he may fail; and let him urge ever so vehemently the temporary presence of some malignant spirit or the nonobservance of some essential rite on the part of those employing his magic or inquiring of his lore, yet his occult wisdom is for the time at a discount and his priestly halo is tarnished. But his influence over the next world cannot be questioned, or if it be, he it is who produces the spirits which bear willing witness to the efficacy of his enchantments and glad testimony to the bliss of the state into which his ability to propitiate the powers of darkness has introduced them. No priest of the middle ages selling his indulgences could have assumed to himself more complete control of the unknown than do these ignorant workers of charms and prescribers of the most abject practices.

The death of a negro in most parts of the West Indies is the signal for ceremonies that appear to be more akin to rejoicing than to the natural expressions of sorrow. The night after the death is usually the time selected for burial, even if death took place late in the afternoon. This is partially due to the requirements of the climate, which make it almost impossible to keep a body for 24 hours; but it is even more largely due to the fact that in most cases the room occupied by the corpse is sadly needed in the hut, where perhaps eight or ten persons of various ages sleep in a space not more than 12 feet square. When the friends and neighbors of the deceased have assembled, the corpse will be found dressed in its best, bedecked with such ornaments as the family can afford and with such charms as the Obiman may furnish or prescribe. But it will not be in its coffin prepared for burial, but in a sitting posture in a chair of state, as it were, where it can act as the center of the drunken orgy that is likely to follow. In some respects the performances which preceded the placing of the body in its coffin closely resemble the conventional Irish "wakes," though the testimony of many African travelers leaves no room for doubt that there is only a fancied connection between the two, as these same practices are found in the interior of Africa, where European customs have not yet had a chance to make themselves felt.

The nearest relative of the deceased, be it wife or husband, mother or child, assumes the leadership in these strange practices, in which the prominent features are the drinking of *tafia* (new rum) and the eating of the best that the relatives can provide, the first of all of which is offered to the corpse with much ceremony and dignity. As it becomes evident that the bearers who are to carry the body are in danger of becoming too unsteady to perform their duties, the drinking is brought to an end and the whole party repairs to the grave. Frequently this is within the small inclosure, surrounded by a cactus hedge, in which is the house of the deceased. At times, where there is both a town and mountain residence, the corpse will be removed from the former to the latter, or *vice versa*. In some cases the burial will take place in a regularly consecrated graveyard, though this is rare among the poorer classes, as the comparative disproportion of such interments and the dense populations show. If the burial takes place at some distance, the stranger returning late at night from the house of some hospitable friend is likely to hear a roar of voices approaching him, oddly mixed with the sounds of tin fifes, the rattle of conch-shells filled with pebbles, and the dull, monotonous boom of the tom-tom or native drum. If the deceased has filled an important niche in his little world, he may also be accompanied by a guitar or violin, which in the hands of an untaught black is capable of adding greatly to the general hubbub. Then appear a motley crowd, of all colors, from the quadroon to the griffe and the lusterless black of the Corymantyn negro, and of all ages and every condition of apparel, from the bedizened chief mourner to the naked boys and girls just budding into puberty. Such a crowd, perhaps a hundred or more in number, will sweep by on the run, the corpse on the shoulders of four brawny negroes, all in the concourse yelling, screaming or shrieking at the top of their voices. It was such a sight as this that a well known New York hotel man met on a lonely road one night outside of Kingston, Jamaica. Having gone to that beautiful island to take charge of a new hotel, then building, he was so horrified and unmanned by such a sight, as he walked homeward from the house of a friend, that he was for days strongly tempted, as he put it, "to pull up stakes and go back to God's country." Months afterward, when he was wont, with dilated eyes, to tell of that night's experience, he always wound up his narrative with: "And there was that coffin *with the lid off* and the corpse looking as badly frightened as I felt."

When the grave is reached, the ceremonies are likely to take for the nonce a more decorous turn, as with that strange blending of wild superstition and Christian devotion which is the African's most interesting characteristic, the parson or priest may be there to perform a few hurried rites and then hasten away before he is compelled to be a witness of how impotent are his teachings to really modify the inborn savagery of his people. After his departure, as the grave is being filled, the musicians quickly start the *chica* or the *bamboula*, favorite dances of the most lascivious sort, and then begins an indescribable scene, a seeming mixture of the French can-can ball with the well-known negro "walk-around," with all its grotesque posturing and laughable assumption of dignity. Never is one more inclined to chime in with the thought expressed by a French admiral who after watching such antics as these turned to his white guide, saying: "Est-ce que vous prenez ces gens au serieux?" Verily, it is indeed difficult to take them seriously.

With the incantations and occult rites of the Papaloi or Obiman, known as *wanga* among the French negroes and as "workin' de Obeah" among their English cousins, the ceremonies at the grave terminate; but they are carried on with even more gusto and with far less describable features at the house of the deceased and at adjoining huts and cabins. In these the vaudoux priest and priestess are prominent factors, and the remaining hours of the night witness scenes of savage debauchery which even beggar the powers of description of the Haitian-French *patois*, a dialect richer than others in words wherewith to express obscene and erotic ideas. As Sir Spenser St. John has said of Haiti, "the Papaloi [vaudoux priests] lead the most depraved lives. They are feared by all, and the fear inspired is so great that few women among the lower orders would resist their advances. They may probably be looked upon as an honor." This is true of the Obiman or witch doctor pretty generally throughout American negrodom; their demands or suggestions are obeyed unquestioningly. Many a new-made widow of the night before has awaked a bride (save the mark) on the morrow.

These burial orgies are always followed by a period of lassitude and rest; but on the arrival of the "ninth night," ceremonies of equal freedom from moral restraint take place. In some of the British West Indies laws are on the statute books and strict rules exist among the churches against these heathenish practices, but so inground are they that civil authority and religious teaching are alike unable to keep them within reasonable bounds. Only in a few of the more fashionable suburbs of the larger cities are strenuous efforts made to check these *wauga* ceremonials, and even there the effort is frequently abortive.

The final acts which in Obeah enable the Obiman to promise to the relatives of the dead safe entry into and happy life in the hereafter are witnessed by but few chosen friends besides the chief mourners, and very few whites have been able to steal in upon these occasions. In one case I was fortunate in being able to watch these ceremonies from the dense shade of a genip tree (*genipapa*), when I discovered that an apparently senseless jargon of words, a liberal display of unusual and rather grewsome relics from dead humanity and from the most dreaded native animals, such as snakes, the wild boar, iguana, alligator, and the barracouta, with some colored fire and wonderful acrobatics, were the cheap stock in trade of the impostor, who probably reaped a handsome sum from the ignorant dupes who surrounded him. A day or two afterward I visited this grave and found it decorated with many broken bits of household crockery, old iron utensils, a wooden cross from the arms of which dangled ale bottles filled with human hair and the viscera of lizards—most potent Obeah charms—some bright bits of cotton stuffs, some strange vegetable growths and a liberal display of ribbons and feathers. Mr. H. C. Bolton, in the last issue of the *Journal of American Folk-lore*, in an article on "Decoration of the Graves of Negroes in South Carolina" (vol. 4, p. 314, Sept., 1891), calls attention to habits of grave decoration which are precisely similar to those of which I speak. And in the *Century Magazine* for April, 1891 (p. 824), Mr. E. J. Glave describes like practices in Africa, and illustrates his remarks with a sketch of the grave of a Congo chieftain. This, Mr. Bolton says, might well serve "for the picture of one in the Potter's Field, Columbia, S. C." To which I would add that it is also a faithful representation of what may be seen in many parts of the interiors of the West Indies, from Jamaica to Trinidad.

This marked similarity in burial customs is observable among the negroes in varying degree from Virginia to Demerara and from British Honduras to the Mountains of the Moon in East Africa. It should speak volumes of caution and advice to our foreign missionary organizations, who to-day are trying to do in Africa, with a handful of men, what three centuries of Christian rule have not brought about in the West Indies and two centuries in some parts of our Southern States have failed to produce save in a very superficial way. In my opinion, when Mr. Bolton says, "The negroes of South Carolina . . . are *unwittingly perpetuating* the fetishism so deeply impressed" upon their African ancestors, he aims wide of the mark. The italics are mine; the words italicized convey, I feel sure, a very erroneous idea, for there is ample testimony in print to show that this continuance in the path of vaudoux and Obeah on the part of many of our Southern negroes is far from unwitting, but is only the most open act of an otherwise carefully hidden superstition. This is an interesting field for both the missionary and the student of folk-lore; if neglected and allowed to grow into cannibalism and other brute practices, as it has done in Haiti, it will soon also become a serious study for the social economist and the statesman.

REMAINS OF WONDERFUL ANIMALS.

IN a recent issue the New York *Sun* describes a remarkable collection of fossil remains that is about to be transported from New Haven to Washington. "Beasts with backbones full of hot air, and separate brains to wag their tails with," remarks our contemporary.

"In this wonderful parade will be gigantic reptiles as big as good sized houses, some of them 100 feet in length, flying dragons with a 25 foot spread of wings, huge birds with teeth, mammals two or three times as big as elephants, sharks as large as the hugest whales, other fishes clad in mighty plates of armor, and countless specimens more of equal strangeness and enormous dimensions, such as actually inhabited the world before man arrived in it. For nine years past the government has been digging up and putting together the skeletons of these strange creatures, and now the vast collection, at present stored in New Haven, Conn., is preparing for shipment by rail to the National Museum. The whole of it would occupy fully one-half of that institution's building there, and so only a portion of it is to be forwarded immediately, the rest to follow as soon as quarters have been established by Congress for its accommodation.

"The business of digging for these tremendous fossils is carried on pretty much like any other mining. In various parts of the West there are great deposits of them, into which the scientific enthusiasts eagerly delve for relics of epochs thousands of centuries old. One of their chosen hunting grounds is the region between the Rockies and the Wasatch Mountains. Ages ago the upheaval of these hills by geologic action cut off the portion of what had been sea between these ranges from the ocean, and the water thus shut away formed many big lakes. A typical one of this sort existed in Wyoming, and around it the mighty antediluvian mammals gathered in herds to crop the succulent and luxuriant vegetation of what was then a tropical climate in that region. They died natural deaths or became mired in the mud when they went to drink, and the sediment slowly deposited in the water covered up their bones and preserved them from decay. This sediment reached a mile in thickness, holding between its layers the ancient skeletons, distributed like currants through a cake. At length the water draining off, left the land dry, and, in the case of the Wyoming lake referred to, subsequent floods washed away much of the sediment previously deposited, leaving what are now called "bad lands"—picturesque with cliffs, peaks, and columns, carved out in fantastic shapes and of variegated coloring.

"Through such a region as this the scientific explorer travels with his eyes as wide open for fossils as the gold hunter keeps his for the shining metal. If from the face of some rocky cliff he chances to see a bone project, exposed by the action of water that has cut away the hillside, he sets a party of men to quarrying with drill, blast, and pickax, until whatever is there in the way of remains has been taken out. Possibly some great deposit of prehistoric monsters may be struck in this way, in which case the find is kept as secret as possible, being regarded by the discoverer as his private mine. If he gave it away, rival paleontologists would rush to the spot and dig out all the animals for their own study and glory. Professor O. C. Marsh, who directed the gathering of the government collection referred to, has such mines of his own all over the West, from which he can draw to order the most astonishing variety of gigantic creatures. He made the remark the other day that there was one small valley he knew of, where relics of the ancient mosasaurus were so plentiful that, passing through it recently, he noticed skeletons of six of those mighty swimming lizards, each eighty feet in length, in sight at one time.

"Usually these amazing fossils are found embedded in solid rock. After they have been roughly quarried out, the sandstone or other matrix inclosing them is carefully chiseled away from the bones. The latter receive a coat of glue to keep out the decomposing air, and any that are broken or splintered are bound up with twine, after which they are packed for shipment. When one of these beasts of antiquity died, its carcass being covered up with sediment that afterward became stone, the skeleton was apt to be preserved entire and with its parts in position, all ready for mounting in a museum. A new reptile was found in Wyoming the other day in such a complete state, which has been named brontosaurus. It was 60 feet long, stood 15 feet high when alive, and weighed 20 tons. Cast in the rock from which it was taken was a perfect mould of one of its eyeballs, with which it looked upon the world three millions of years ago. It had a very small head, a long and flexible neck, a short body, and a huge tail. In the same neighborhood also has been discovered recently another reptilian monster called the triceratops, which had an enormous bony frill around the back of its neck. This surprising development, measuring six feet across, was intended for the attachment of great muscles that were necessary for holding up the huge head. The animal, though tremendously massive, was only thirty feet long; but it was covered with plates of armor and had a sharp and horny beak, not to mention a horn on its nose and another on its forehead, the latter 2½ feet in length.

"In Colorado have been found great deposits of the bones of titanosaurs, the biggest land animals that ever existed. They grew to be 65 feet long and stood 40 feet high when erect upon their hind legs. Instead of browsing, as did the brontosaur and triceratops, upon the luxuriant aquatic vegetation around the lake borders, they fed upon the foliage of trees on the mountain sides. Likewise did the iguanodon, several times as heavy as an elephant, which had a nipping beak like a turtle's and also walked erect, using its huge tail for a support and towering to the height of 40 or 50 feet.

"In the mesozoic epoch, or 'Age of Reptiles,' when those creatures lived, these and other herbivorous animals were the biggest of the beasts. One of them, the atlantosaur, was 100 feet long, its thigh bones, many of which have been found, measuring eight feet in length and twenty-five inches through. They had various methods of pursuing existence. Some went on all fours and had backbones that were mere shells filled with warm air from their lungs, which served them as floats while they walked in the sea shallows in water deep enough to cover their backs, extending their long necks to crop the vegetation alongshore. Of this sort was the camerasaurus, eighty feet in length. Others had enormously long hind legs, on which they were able to wade out far into the ocean after seaweeds, and were provided with not fewer than 2,000 teeth for grinding their food. Such was the mighty kangaroo-like hydrosaurus. Yet other species dwelt on land, like the triceratops, and these were provided usually with armor and horns for defense.

"It would seem as if such monsters as are described need have feared no living foes, but in fact they were a common prey to great numbers of frightful carnivorous reptiles, smaller in size, but of tremendous activity and fierceness, which fed upon these unwieldy, vegetable-eating giants. Most terrific of all, perhaps, was the incredibly ferocious laelaps, which was forty feet long, stood twenty-five feet high on its hind legs, and was built like a kangaroo. It was the most astonishing jumper that ever existed, with teeth for cutting, and sharp claws on the front feet, evidently designed for tearing out the eyes of victims or adversaries. Hardly less formidable, and equally large, was the stagosaur, which was sheathed in armor plate from two to three feet wide, and employed as a weapon of offense its powerful tail, armed near the end on both sides with sharp spikes two feet long. This animal walked erect also, and one of its peculiarities was a great enlargement of the spinal cord at the lower end of the back. In fact, this expansion of brain material, intended to provide for the wagging of the mighty spiked tail, was ten times as big as the brain in the skull itself. Equally large and dangerous were the megalosaur and the dinosaur, their jaws armed with huge saber-like teeth, which went about on their hind legs looking for something to devour. Against such fearful foes what chance had the peaceful cetiosaurus and elasmosaurus, dwelling in marshes and shallows, with the bulk of six or eight elephants? Nevertheless, some of herbivorous land reptiles referred to, like the gigantic horned and armored agathumas, could make a good fight with the carnivores, and were so well able to defend themselves that they lived and multiplied in the same region with the latter. But most of these vegetable feeders had no other means of defense than kicking, which they could do with some effectiveness with hind legs fifteen feet or so in length.

"Specimens of all these are included in the collection which is to be brought here for permanent exhibition. Of course, they represent but a few of the countless species of giant beasts that roamed over the earth in droves during this vanished epoch. That was the age when reptiles ran the creation. They walked upon land, swam the seas, flew through the air, climbed trees, and did everything that mammals do nowadays. There were bird reptiles and reptilian birds. Some had wings for flying with a spread of twenty-five feet—veritable dragons, in fact. Others, forty feet in length, had paddles for swimming like a whale's. These latter lived in the seas, though occasionally they came on shore. It is known from their petrified droppings, which are plentifully found to-day, that they lived upon fish. One species dived to great depths in the ocean, and was most rapacious and predatory. It had enormous eyes to see with in deep water, its head resembling an alligator's. Another kind with a very long neck inhabited the shoals and preyed upon the fishes of the shallows. The first serpents, too, belonged in the sea and grew to be forty feet long. They had no poison, but were constrictors, like the boa. There were many kinds of crocodiles fifty feet from snout to tail, whereas the biggest ones now are not more than fifteen feet. During the same period lived the birds with teeth, which were only discovered a few years ago. Biggest of these was the hesperornis, which stood six feet high, and had only rudimentary wings. It did not fly, therefore, but was simply a swimmer and diver, subsisting on fish. The ichthyornis was somewhat similar in appearance and habits, but not much larger than a pigeon. It is supposed that these strange water fowl were wiped out by the giant swimming lizards, eighty feet long, and clad in bony armor plates, which resembled the modern conception of the sea serpent. The turtles should not be forgotten, which attained a length of twenty feet, and measured seven feet in height.

"It is not only the age of reptiles, however, that is represented by the unparalleled collection described. Before that came the epoch of fishes, when they ran the world and had all creation pretty much to themselves. Of this era likewise the government has gathered together a vast quantity of fossil relics. The face of the earth did not look then at all as it appears now. Most of what are now called the continents had not been upheaved above the ocean; nearly everywhere was sea, with comparatively small land masses elevated out of it. The atmosphere was hot, moist, and loaded with carbonic acid, so as to be unbreathable. In the waters swam enormous armored fish, such as the dinichthys, which was fifteen feet long and had such tremendous jaws and teeth that it could have bitten a man in two as easily as you would a radish. Later on came sharks of the fiercest type, which must have been as much as seventy feet in length at least. The biggest tooth of a maneater of to-day is about an inch long, while the teeth of these ancient sharks, found in enormous numbers, measure more than six inches. That was the golden age of the scaly tribe.

"The giant reptiles that appeared on the scene in the subsequent epoch were remarkable for the smallness of their brain cavities. In some of them the brain was so small that it could have passed without injury through all the vertebræ of the spinal column down as far as the beginning of the tail. All of them were wiped out of existence by the great cataclysm which upheaved the Rocky Mountains, the Alps, and Himalayas, and brought to a close the mesozoic epoch. Then came the age of mammals, at the end of which we are now, man being the last arrival on the scene.

"The age of monsters pretty nearly has passed away, only a few remaining, like the elephant and the whale. Small animals with plenty of sense will always survive stupid giants in the long run, because they require less food and know better how to avoid danger. Observe in illustration how the doom of extinction has fallen upon the gigantic mammals which roamed over the earth by myriads only so short a time ago, comparatively speaking, as the beginning of the present era, called the cenozoic. There was the dinaceras, which lived in herds about the lakes, as the deposits show, big as an elephant, but in appearance somewhere between the rhinoceros and the hippopotamus, with three pairs of horns on its head and huge saber-like tusks that fitted into sheaths in the lower jaw. More imposing yet was the tinoceras, somewhat similar of aspect and sixteen feet long. Not less impressive was the megatherium or giant sloth, as large as two elephants, and which attained a measurement of eighteen feet, and procured the leaves on which it fed by seating itself upon its mighty haunches and uprooting great trees. Of the dinotherium no complete skeleton has been discovered, but it was, doubtless, the biggest land mammal that ever lived. A full grown skull of this earliest of proboscidians, which had long tusks as well as trunk, measures five feet from the point of the lower teeth to the top of the head. The brontops, of elephantine size, had a head like a rhinoceros, with huge horns. Quite as remarkable was the sivathorium, a beast like an antelope, big as an elephant, with two conical horns on the front of its head and two immense spreading ones behind. Among birds were waders ten feet in height, such as the dinornis and gastornis. Contemporary with them were the mammoth and the mastodon, the woolly rhinoceros, armadillos nine feet in length, and the saber-toothed tiger, larger than the greatest lion of to-day. All that is left of these wonders of animal life is found in deposits such as those of the Western lake beds. For years the government has been engaged in excavating their bones, which are now to make part of what is to be the greatest zoological show on earth."

SONG BIRDS.

ACCORDING to local record, fifteen or twenty years ago the parks and gardens in the heart of Chicago abounded in song birds of brilliant plumage and varied notes. To-day these have generally disappeared, and in their places flocks of vulgar little English sparrows assail our ears with their harsh, scolding chirps. The smoke from ten thousand chimneys and smoke stacks has, no doubt, helped to weary our feathered prima donne of our presence, but a more potent influence in causing their disappearance has been the introduction of this foreign bird, which, as prolific as it is greedy and quarrelsome, by its numbers and its bad manners always drives the milder birds from any locality where it takes up its abode. Wherefore we commend our legislature for setting a bounty on their good-for-nothing little heads, and we hope for the addition of sparrow pie to the regulation restaurant bill of fare, to assist in the extermination of this undesired intruder.

Our song birds are not wholly lost, however. They have simply retreated from the proximity of vitiated air, of roaring engines, of the street gamin with his slung shot, and the scolding and pugnacious house sparrows. If you will follow them to their retreats, you will find them there in force. There are many still left in our larger parks—robins, catbirds, pewits, and wrens. Going farther from the city, to the quiet, wooded shelter of our cemeteries, you will find the oaks and maples there giving shelter to scores of songsters, warblers, finches, thrushes, and others. Some of the choicest of our singers, among them the veery and the song sparrow, may be heard in the quiet retreat of the cemetery of Rose Hill, while in the woods along Des plaines River to the west, and the Fox River to the northwest, you may find the oven bird, the hermit thrush, with greenlets and tanagers besides. On the prairie are still to be heard the vesper sparrow and the meadow lark, while the gardens and orchards of our suburban towns abound in the more common birds—the catbirds, robins, orchard orioles, woodpeckers, and jays.

The robin, known also as the red breast thrush, and in some localities as the American fieldfare, is the most familiar of the song birds in this latitude. Being larger than the English sparrow, he pays little attention to the chattering intruder. He is a friendly bird, and if unmolested by malicious assaults seems to prefer human proximity, and will build anywhere, in trees, bushes, eaves of houses and barns, or the crotch of a fence. The robin is one of the earliest birds to return to us from the South, usually appearing in March, and his first song, though weak and unmusical, is always heard with pleasure, for it is the harbinger of spring. Practice improves this bird's notes, and the cheerfulness of this song largely makes up for its imperfect execution. The robins make their nests early in April, and always raise two broods in a season, sometimes three. The male and female robin are much alike in plumage. The head and neck are blackish, with streaks of white on the throat, the wing and tail are a dark slate color, and the breast is of a peculiar reddish ocher tint. The young in the first year are brownish gray, the breasts pale ocher. The robin is a greedy bird, and takes toll from the raspberry and currant bushes, and especially from cherry trees, without conscience. Those who know the bird, however, do not find much fault with him, for they know that he has well earned his fruit feast by devouring the fruit spoilers, worms, and caterpillars. Professor Treadwell, of Cambridge, once undertook to bring up several small robins. He found that to keep them from starving to death, it was necessary to allow them every day the equivalent of their own weight in insect food or worms. Each little gourmand required daily sixty earth worms or 250 average insects.

The robin is really a thrush, and so is another familiar bird which vies with the robin in impudence and voracity—the cat bird. So also is a very pleasing songster, known to suburban dwellers—the brown thrasher. The name is usually confined, however, to a group of birds best known to us through their fine gift of song. They are the songsters, par excellence, of our groves. Four species of thrush—the wood thrush, the hermit thrush, Wilson's thrush, and Swainson's—can be observed with greater or less frequency in Cook Country every season.

The wood thrush, also known as the bell thrush, the bell bird or the wood robin, is noticeably larger and richer in color than the others; is cinnamon brown above, tawny on the head, wings duller than the back, tail gray brown, breast white with a buff tinge, and spotted with black. Every one who has haunted woods knows the song of this bird at least. It is a rich, bell-like melody of peculiar sweetness, a song which no one with any perception of musical sounds can ever forget after once hearing. This bird is almost identical with the song thrush of England, and the mavis of Scotland, though its song is pronounced finer by critics. Like the Old World bird, he has the habit of singing his song through, then going back to the beginning and repeating it, note for note, exactly as at first. Of this, the poet Shelley says:

"There's the wise thrush, he sings each song twice over,
Lest we should think he never could recapture
His first fine careless rapture."

It may be remarked that the thrushes are all much alike, and that no one but a bird student can distinguish between them. They are alike in outline, and all have brown backs, and breasts a dull white more or less spotted. But Wilson's thrush, also called the tawny thrush, has a distinct reddish tinge above, and Swainson's thrush, also called the olive-backed, is plainly greenish, while the hermit thrush may always be known by a reddish tail. All are similar in their movements, but differ most markedly in their song notes.

Two of the handsomest song birds known are frequently seen near Chicago—the Baltimore oriole and the orchard oriole. The latter can be seen in any one of our cemeteries every season and in hundreds of suburban apple trees, but the Baltimore bird is only an occasional resident. During the last summer, however, a most beautiful specimen of the latter species in full plumage was seen at Rose Hill. The orioles are nearly all natives of the New World, the genus including some magnificent tropical birds found in the Amazonian forests. These birds all make hanging nests. That of the Baltimore bird is a purse-like pouch about seven inches deep, made of hemp and hay, closely woven and lined inside with horse hair and other soft substances. The name of this bird was given to it because the colors of the plumage of the male bird—black and orange—were the livery of Lord Baltimore, the first Governor of Maryland. It is also known as the golden robin, the fire bird, and the hang nest, and probably by other local names. The male does not have its perfect and brilliant plumage until he is three years old. Then his head and neck, back, wings, and two middle tail feathers are a beautiful shining black, while the lower parts and the side feathers of the tail are a rich orange. The female is so different from the male that the casual observer would never suppose her to be of the same species. She is olive green, dull orange and white. The young are like the female for the first two years of their life. The song of the Baltimore bird is a mellow whistle with a peculiarly mournful tone in it. It is not short and quickly uttered as most bird whistles are, but is repeated by the bird as he moves among the branches searching for insects, with a careless deliberation, like that of a boy whistling for his own amusement.

A survey of our familiar birds cannot fail to take in several native varieties of the sparrow. These are less known in our smaller parks than they were some years ago, but just a little outside of the circuit which the English bird has chosen to appropriate as his own they are still to be found in numbers. In the open land to the south and southwest of the city, and the locality once known as the Calumet Marsh, the greatest number of varieties may be found. Nelson's sparrow, a handsome little fellow with blue gray back and yellowish breast, was first observed by an ornithologist, some fifteen years ago, in that marsh. Of the sparrows that we know in the lake shore district generally, the fox sparrow, the song sparrow, the red billed field bird, and the tree sparrow, nest in close thickets or briar bushes; the vesper bird, the lark sparrow, the white throated, the chipping, and the swamp sparrows, seek more open space. The two species which fraternize most kindly with the English sparrow are the chipping and white-throated sparrows. The latter is often known as the peabody bird from its note; it is one of the largest sparrows. The chipping sparrow is one of the smallest, is very tame, and has much the same note as the English sparrow, but is known from his foreign cousin by his lighter color and more agreeable manners. The field sparrow is known by his red bill. The song sparrow has a back of ruddy brown striped with black. It has a white breast, with dark lines running down from the throat. The song of this bird is fine, and it sings a great deal; still, in vocal power it is surpassed by three other species—the fox, vesper, and lark sparrows. The last named is a bird found on prairie meadows having a growth of rank weeds, and also in corn fields. Its song is delightful, being a series of chants, every note rich loud, and clear, with thrills that would make Mme. Patti-Nicolini turn green with envy. This sparrow is one of the few birds that will eat the potato bug, for which he is rewarded by being poisoned with Paris green.

The sparrows are all hoppers and scratchers; they do not walk or run; they hop, and they scratch with both feet at once. They differ so little in size and in habits and appearance that the casual observer distinguishes them apart more readily by their songs than by their plumage. But observation finds their individual differences very striking.

The sparrow genus belongs to the large family of finches, in which is also classed the bunting genus. We have three buntings in this locality—the indigo

bird, the towhee and the blackthroat. Oddly enough, the first named of these is indiscriminately styled blue linnet and green linnet in different localities. This is because the peculiar blue of its plumage, tinged with ultra-marine on the head, throat and breast, shades on the back to a bright verdigris green. The blackthroat bird is the well known "Dick Cissel," so called for his peculiar song, and also known as the little field lark. This bird is gray and black with a yellow breast. Of the towhee bunting one should make particular mention, for one seldom visits a wooded spot north or south of the city and fails to hear his peculiar note. This bird has a whole budget of popular names, chewink, towink, jaree, ground robin, and turkey sparrow. The male of the species is a handsome bird with back, head, and throat a glossy black, and breast a clear white. The tail is black, edged with white. It lives usually in thickets and rank, tangled bushes. It keeps for the most part on or near the ground, and scratches among the leaves, like an old hen, for insects. It never flies far or high. You will notice it most often hopping and sidling in and out through the bushes and brambles, with a nervous movement very like the sparrows, and often with its tail perked up after the manner of a wren. Every little while it will give its call, "chewink," with a prolongation of the last syllable. You cannot fail to know its note, and it has no other song.

Seated under the spreading trees in Rose Hill Cemetery in the warm, still afternoons of June, we notice that song sparrow, thrush and oriole are quiet, weary with their morning warblings and oppressed with the summer's heat. Then through the windless air comes the soft note of the turtle dove, harmonizing far more in its exquisite, tender sadness with the atmosphere of the place than does the joyous melody of the other songsters. The dove is not, properly speaking, a song bird, but its note forms a part of every woodland chorus. This soft cooing note of the dove, the one by which we know it, is the one which it uses in wooing its mate. With us the bird usually nests in bushes; in the Southern States it builds on the ground, while in Arizona, we are told, it puts its nest on the thorniest cacti to protect it against venomous reptiles. The male dove is a beautiful bird. His head is bluish gray with a peculiar "bloom" or sheen on the feather, shading into cinnamon color on the throat, and changeable purple on the side of the neck. The breast is a purplish pink, shading to creamy buff below. The back and tail are bluish gray. The female is like the male, but with less blue tint, and the breast is brown. The young is still more brownish, and has no gloss on its feathers. All the adult birds have a distinct black spot beneath the ears; this does not appear in the young.

A group of birds that must be mentioned because of their beautiful plumage and their familiar presence in our latitude is that of the woodpeckers, also vulgarly known as sap-suckers. Four species are well known here—the golden winged, the red headed, the hairy, and the downy woodpeckers.

The golden winged woodpecker, also called the yellow hammer, is a familiar denizen of the suburbs. He is accused of eating the young corn, tearing off the husk and devouring the soft, milky kernels, also of spoiling the best apples and pears by thrusts of his greedy bill, and truth compels one to admit that both counts are well sustained. Because of these depredations, and being himself a dainty morsel for eating, he is a frequent victim of the sportsman's gun. This bird builds its nest very high, hollowing out a place for it in the solid trunk of a tree, after the manner of all its species. The male and female birds work alternately at this task of digging out the wood, and so intent upon it do they become that they can be heard, during its progress, from the first peep of dawn until hours after dark, thumping like carpenters. From the situation of its nest, the yellow hammer is also known as the "high-hole." It is also known in the Eastern States as the "flicker," among the Pennsylvania Dutch as the "yucker," and as the "hittock" or the "pi-ut" with the negroes in the South. These names have reference, no doubt, to its note, which is a call of two syllables, frequently repeated, and might be translated into almost anything. The yellow hammer is a handsome bird, with brown back, and wings brown on the upper part and bright yellow below. He has a red spot on the back of the head and a crescent-shaped spot of black on the throat. The breast is a yellowish white, with little spots of black. The female is like the male, but has much duller plumage.

Every child in the land who has any knowledge whatever of the woods has seen the red-headed woodpecker. He is as much of a marauder as the yellow hammer, raiding the orchards and the corn fields, and his polite endeavors to pay for what he thus appropriates by devouring borers and caterpillars are but imperfectly appreciated. The farmer peppers him with small shot and the farmer's boy pelts him with stones. For all that, he is a gay, frolicsome fellow, and on soft June afternoons, when the Madam Woodpeckers are all brooding quietly in their nest holes, a half dozen of the male birds may be seen around the dead branches of some old tree, chasing each other through the air, now diving, now sailing aloft, apparently engaged in some sort of leap-frog game known only to woodpeckers, making the air ring the while with their peculiar calls. Their note is shrill, not to say harsh, and is very much like that of the tree frog, for which it is often mistaken. This bird has the entire head and neck deep scarlet; the upper part of the back, outer wing feathers and the tail are black, with a gloss of blue, and the lower part of the back or rump, and the entire breast, are pure white. The female differs from the male only in being somewhat smaller and having a less vivid plumage.

Another bird known to every schoolboy, and claiming notice on the score of old acquaintanceship, if for nothing else, is the blue jay. This bird is a resident in our woods from Texas to Canada. His plumage is light purplish blue on the back, and beneath white, with a faint bluish tinge. He is a handsome bird, but his fine feathers make him no friends, for he is a worse marauder in cornfield and orchard than the yellow hammer, and plunders the nests of small birds worse than the owl, devouring their eggs and tearing and eating the callow young. He has quite a talent for mimicry and can imitate the cries of other birds, but is best known by his own peculiar call, which is a loud "caw!" only less harsh than that of the crow. The jay can be tamed, and can be taught as many tricks as a magpie, even to articulate speech.

We have charged the English sparrow with being responsible for the disappearance of our smaller song birds from the once favored haunts in the shade trees of our yards. But this pugnacious bird, like the enemy of mankind, should be allowed his due. Bad as he is, he has not worked one-hundredth part of the evil that foolish fashion has done. He has bullied wrens, blue birds, lark sparrows, and other small songsters, until they have, for the sake of peace, moved on to spots less encumbered with his presence. But we owe it to the senseless and brutal desire of "gentle woman" to adorn her headgear with the dead bodies of these harmless little creatures that the tanagers, the grosbeaks, the greenlets, the red polls, the humming birds, and other bright plumaged singers, once so numerous in this part of the State, are now only found in secluded localities; that but one or two pair are seen even there, where formerly a dozen happy couples might have been found; or, it may be, a particular species only appears once in several years. The fact that the gunners dispatched on their murderous errand by a single New York wholesale millinery house sent north from Florida last winter 10,000 of these slaughtered innocents solves the question of the disappearance of our song birds with terrible distinctness.—*Inter Ocean.*

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